IBA TECHNICAL REVIEW

7

Service Planning and Propagation

IBA INDEPENDENT BROADCASTING AUTHORITY

IBA TECHNICAL REVIEW July 1976
ISSN 0308-423X

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Contents

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NOTE:

Code of Practice for the Technical Performance of Television Transmitting Stations.

Under the terms of the Independent Broadcasting Authority Act 1973 the IBA is required to ensure that high quality technical standards are provided and maintained. The Authority's Code of Practice for the Technical Performance of Television Transmitting Stations, which is referred to in the following articles, sets out the tolerances and standards to be aimed for on a day-to-day basis. The Code is reproduced in *IBA Technical Review 2: Technical Reference Book*.

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INDEPENDENT BROADCASTING AUTHORITY

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Introduction

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An earlier volume of this Review dealt with the design and construction of the Authority's growing network of stations which transmit the programmes so that they may be received in different parts of the country by television viewers and the listeners to Independent Local Radio. The articles contained in this present volume deal mainly with the initial planning which forms a somewhat earlier stage in the process of establishing a television or radio service.

Service area planning, as it is called, has always been an essential pre-requisite to any network of transmitting stations, but with the introduction of colour television on 625 lines in uhf it became necessary to tackle the planning in an especially systematic and detailed way. From the beginning it was recognised that to achieve a high proportion of national coverage for four television programmes in the uhf band would raise many problems. Due to the comparatively large number of stations required and the limited number of frequency channels available, a complex mutual interference situation was anticipated which could best be tackled by the use of computer techniques.

Time has demonstrated the importance of the initial planning standards laid down more than ten years ago. Now that these uhf services are available to over 96% of the population we can see how difficult it is to extend them to the remainder. This problem was considered by the Television Advisory Committee in 1972 amongst other matters, and was later made the specific remit of the Committee on Broadcasting Coverage (Crawford Committee) which reported in 1974. Whilst there is undoubtedly some scope for distribution of television and radio by cable, particularly in urban areas, there seems little doubt that many more television transmitters – albeit of fairly low power – will be required to complete national coverage.

It is of interest to note that the present amount of coverage is provided by 47 main stations and 185 relay stations. These latter are generally smaller than main stations – in some cases very much smaller. The present phase of planning, which is nearing conclusion, is concerned with stations which can serve areas each containing more than 1,000 people. To complete this phase will require the construction of a further 200 or so stations. The next phase, which was recommended by the Crawford Committee, will be to consider those remaining areas which each contain between 500 and 1000 people. Planning for this phase is still in the very early stages but it is anticipated that some 250 additional relay stations would be required. One problem which has been encountered is the shortage of frequencies for all these extra stations. This shortage is particularly acute in certain parts of the country where, in effect, it sets an upper limit to the number of people who can be served within the presently allocated uhf band.

As planning extends to smaller and smaller unserved communities it becomes increasingly necessary to know in great detail the extent of the coverage provided by existing stations so that new ones can be accurately and economically planned to fill the gaps. Hence, the initial planning of new stations is partly theoretical in that it deals with the assessment of eventual coverage by transmitting stations not yet built, but in another respect it is very practical since it includes the measurement of signal strength from stations currently in service.

The techniques employed in the general field of service area planning over the past few years have become gradually more sophisticated and refined. In

particular, the rapidly increasing number of inter-related stations has inevitably led to a vast bulk of information which needs to be handled by computers. These are virtually essential to record the complicated interference situation on uhf television channels and they have also proved extremely useful in determining the coverage of transmitting stations in terms of both population and area.

Another very practical problem is the need to supply each transmitter with a programme feed. In many cases this is achieved by direct reception of the programme transmitted by a station already in service; in others it is necessary to plan and install microwave radio links, and one of the articles that follows is entirely devoted to this.

But technical matters apart, there is one area of activity which, though strictly outside the limits of engineering, is so essential to the planning and setting up of a network of transmitting stations that no treatment of this subject would be complete without it. Accordingly, we make no apology for explaining at some length the problems of acquiring sites for broadcasting stations. Technical or not, the detailed negotiations with landowners and the obtaining of the necessary consents under the Town and Country Planning legislation are just as complex in their own right and can be a most time-consuming part of the process of providing a new station.

In addition to the IBA television stations there are now 19 Independent Local Radio stations in operation serving an estimated 45% of the population. This is a limit set for the time being by the present Government. However, tentative frequency plans have been formulated for a total of 60 stations, as envisaged by the 1971 White Paper 'An Alternative Service of Radio Broadcasting', each operating in both the vhf and mf bands. It has been estimated that together these might serve about 65% of the population of the United Kingdom.

Many of the problems of planning a television service have their analogues in planning a service for sound radio. However, in the mf band there are additional problems since this part of the frequency spectrum is extremely congested and there is considerable interference arising from stations in other countries. This is another field where computer techniques have come to the fore in recent years.

These various subjects are dealt with in the IBA by the Network and Service Planning Department, whose staff have provided all the articles in this volume.

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Planning Medium Frequency Broadcast Radio Services

by F H Wise

Synopsis

In recent years, comparatively little planning activity has been directed to providing new broadcasting services for the medium wave band in Europe. In spite of it being overcrowded, the mf band still offers certain attractions, particularly for the developing nations, and in 1973 a decison was taken to replan lf and mf broadcasting services in Europe, Africa and Asia. This new plan will come into force in 1978.

The paper outlines those technical factors which were used in drawing up the plan. They include the methods to be adopted in establishing the field strength of the ground-wave, which normally determines the strength of a wanted signal, and of the sky-wave which, in general, constitute interference after dark. In addition, some of the characteristics of transmitting aerials are explained, and the administrative procedures by which the plan may be modified in certain circumstances are discussed.

Introduction

In recent years in Western Europe there has been comparatively little development of mf services as most planning activity has been concentrated on expanding television coverage, and any development of radio broadcasting has been mostly in vhf Band II. There are two main reasons for this. First, there is no doubt that the fm standards adopted for vhf allow reception to be of a substantially higher quality than is possible using a.m. in the mf band, and second, that the technical standards which were used in regulating the existing mf plan (European Broadcasting Convention, Copenhagen 1948) allowed little scope for accommodating extra assignments without objections from existing users of the frequencies concerned. In spite of these factors there has been interest in the expansion of mf radio services if only because, at least in the UK, many listeners prefer the convenience of inexpensive portable receivers with ease of tuning, low battery consumption and without the need for cumbersome rod aerials such as are required for vhf reception.

One of the attractions of mf broadcasting is that the coverage of any one station may, in principle, be very large. Often this can be of advantage to the listener who, having learned the 'spot on the dial', may be sure of finding the desired station even in different geographical locations separated by comparatively long distances. This can be especially useful to car-radio listeners who thereby avoid the bother of re-tuning as often as when receiving vhf signals. Experience has also shown that, although there is no fundamental reason why it should be so, the characteristics of the electrical systems of many vehicles built in the UK are such as to cause significantly more interference to vhf reception than to mf reception.

For these various reasons, and despite the difficulties associated with interference to mf reception during the hours of darkness, the use of the band remains

popular in Europe and has great appeal in the developing countries where it is being used in establishing initial broadcasting networks.

Against this background the decision was taken in 1973 to replan lf and mf broadcasting in Europe, Africa and Asia. This new plan is to replace the European Broadcasting Convention (Copenhagen 1948) and the Africa Plan (Geneva 1966). It was clear that the task would be extremely large, and for that reason the work was split into two parts. The first part was the determination of the technical parameters to be used in the planning. This was dealt with during the Regional Administrative Broadcasting Conference (RABC), Part 1 held in Geneva in October 1974. The final part of the work, that of agreeing specific frequency assignments and the terms of the agreement, was dealt with in Part 2 of the Conference held during October and November 1975.

In this article the various factors to be taken into account in planning mf broadcasting services are considered, and some additional information is given on the way in which modifications to the new plan (Geneva 1975) may be implemented.

MF Propagation

Although all electro-magnetic radiation obeys the same basic constraints, the practical effects of the different factors determining the strength of signals transmitted in the various frequency bands differ widely. For example, in the uhf band used for television it is, in virtually all cases, only the space-wave which needs consideration. But, in the mf band a space-wave is unimportant during the day as only the ground-wave propagated along the surface of the earth is then significant. For this mode of propagation it is principally the conductivity of the ground which determines the attenuation with distance of mf signals at any given frequency.

A well-known phenomenon of mf propagation is the enhancement of signal strength of transmissions from different stations after dark due to sky-wave transmission. In any situation where there are very few powerful stations on any one wavelength, the effect would be to make possible reception from other, more distant stations after dark than during daylight hours. Thus, for stations of power 50 kW or more, the possibility would exist of considerable increase in coverage after dark. Less powerful stations would, of course, generate a sky-wave signal, but its strength would be insufficient to provide reliable reception.

Taking account of the crowding of frequency assignments in the mf band no practical use can now be made of this effect. After dark, when the sky-wave signals are propagated, the net result is that at any given receiving point there will almost always be signals from several stations sharing the same wavelength and having comparable magnitude. In practice, therefore, satisfactory reception of sky-wave signals is not often possible in Europe although this may not be true in other parts of the world where the physical separation between high-powered stations is much greater.

In Europe, at the present time, satisfactory coverage may be obtained by day; but after dark, with the onset of sky-wave propagation, interference levels increase by at least an order of magnitude so the coverage actually shrinks to a fraction of its day-time value.

The strength of a radio signal is expressed in terms of its field strength, and the most straightforward interpretation of the term field strength in the context of the mf band is the ratio of emf induced in a short vertical wire to the effective height of that wire. It is normally expressed in mV/m, or alternatively in dB relative to 1 μV/m.

In principle, field strength could be determined by measuring the emf induced in a vertical rod. Such a measurement would give directly the magnitude of the electric component of the radio wave, but, because of instrumentation difficulties, an alternative procedure is normally adopted. Thus, in practice, the aerial used is almost invariably a shielded loop which gives an output proportional to the magnitude of the magnetic component of the wave.

In the case of a plane wave, and in a situation where no discontinuities in the ground constants exist, the electric component E and magnetic component H are related by the equation

$$E = 120\,\pi H$$

where E = volts/metre

and H = amps/metre.

Normally, therefore, although a loop aerial measures the magnetic component of the field, calibration can be directly in terms of the electric component. Should there be any discontinuities in ground constants, or any reflecting objects in the vicinity such as steel-framed buildings, this relationship no longer applies and the loop aerial can then only be used to indicate the strength of the magnetic component.

Ground-Wave Propagation

Classical solutions to the equations governing ground-wave propagation were derived many years ago, and it is interesting to scan some of the early papers.[1, 2, 3]

For practical use the equations are too cumbersome, and normally use is made of published curves, a representative sample of which is reproduced in Fig.1. These curves show the variation in ground-wave field strength with distance as a function both of frequency and of ground conductivity. The trend is for the attenuation with distance to be greater at higher frequencies and when ground conductivity is low. Sets of such curves are to be found in ref.3.

It may be helpful to add some remarks on the practical meaning of the term ground conductivity. In the case where the ground is uniform and composed of precisely similar material at all depths, and composed also of material having a conductivity which remains constant independent of frequency, the meaning of the term is fairly clear. The geological structure of the real earth, however, is such that, except in the case of the sea, there is considerable variation in the constituent material near to the surface. So that we may determine the depths to which the characteristics of the earth's surface are significant, the 'skin depth' of the current flow must be calculated, and it has been found that this skin depth varies between 70 m for low frequencies and poor ground conductivity to 20 m for higher frequencies and more conductive ground. For the sea the conductivity is much greater and the skin depth for medium frequencies is less than 1 m. Evidently, for land, the effective ground conductivity will have a value which is close to the mean value averaged over a depth of about 30 m.

There is some practical difficulty in determining this effective ground conductivity although it has been found in practice that surveys made by electricity undertakings, wherein the conductivity is measured to a depth of about 20 m albeit at a frequency of 50 Hz, gives a good guide to the conductivity in the mf band at least on a comparative basis. In some countries the results of geographical surveys are also available and are published in map form. These indicate the structure of the earth in different areas. While this data in itself is not easy to convert to a map showing variation of conductivity, it is often helpful in determining the extent of regions where the

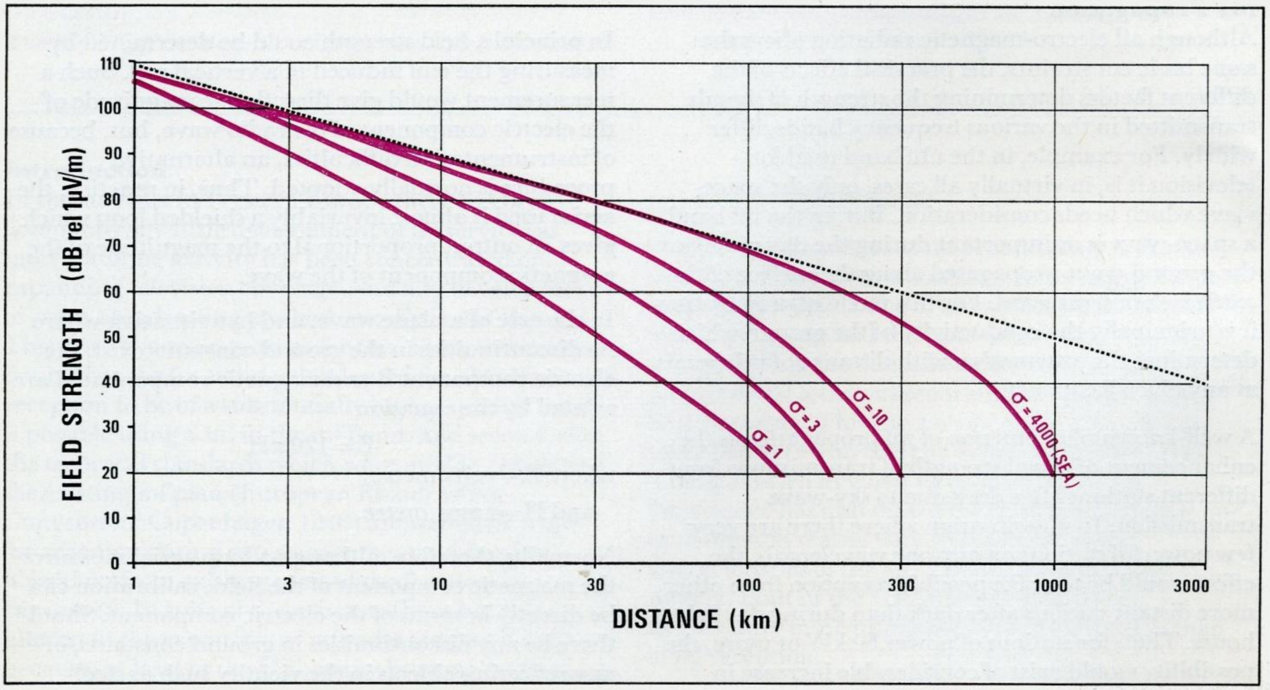

Fig. 1. Variations of ground-wave field strength with distance for a frequency of 1000 kHz and 1 kW effective monopole radiated power (emrp). The parameter σ is the ground conductivity in mS/m. Graphs are published which enable ground-wave field strength to be determined for any frequency in the mf band, and for any practical value of ground conductivity.

conductivity may have been measured by other means.

Various methods are quoted in published literature for determining ground conductivity[4], but in general they tend to be tedious and rather inaccurate. A method more recently developed in Finland[5] appears to give reasonable accuracy, and because the measurements can be made from an aircraft an extensive area can be measured fairly quickly.

Within the UK, ground conductivity generally lies between about 10 mS/m (millisiemens per metre) although somewhat higher values, for example 20 mS/m are found in Tyneside and parts of the Midlands, while rather lower values of about 1 mS/m occur in the mountainous regions of Scotland and Wales.

Given the power and frequency of signals radiated from a transmitter, together with the value of ground conductivity in the area, it is possible, therefore, to determine the manner in which field strength decreases with distance from the transmitter. There are, however, additional factors which may need to be taken into account; for instance, the ground conductivity might not be constant. Where the variation in conductivity is small, use of the mean value will normally provide sufficient accuracy, but where the variation is large, any calculation must separately take account of the different characteristics in different segments of the path. One of the most useful methods of dealing with such a problem is that proposed by Millington [3, 6] and which may be extended to a path with any number of segments.

A special factor of some significance which occurs in the vicinity of tall steel-framed buildings is a disturbance in the relationship between magnetic and electric components of the wave. On average, the presence of tall buildings results in a net attenuation of the field although, occasionally, there are small localised areas where some enhancement is detected. The magnitude of the reduction of the electric component is always appreciably greater than the reduction in the magnetic component. In any modern city, therefore, where the height of buildings may be 50 m or more, the field strength measured using a loop aerial will generally be about 6–10 dB less than would be expected in the absence of the buildings. The field strength measured with the aid of a rod aerial will frequently be less by a further 15–25 dB. These effects appear to be more marked at the higher frequency end of the band and presumably are dependent upon the height of the buildings in relation to the wavelength. One of the practical implications of this is that, in city centres, reception on car radios, for which rod aerials are virtually universal, may be poorer than expected.

Fortunately, most car radio receivers have a high sensitivity and will operate in field strengths considerably weaker than those necessary for portable receivers employing ferrite rod aerials, but it must be remembered that susceptability to man-made interference becomes greater as the field strength of the wanted signal decreases.

If mf reception is required within steel-framed buildings themselves, it is most likely to be with receivers equipped with ferrite rod aerials, and for these the measurement of field strength using a loop aerial would be the more relevant. A limited series of such measurements has indicated that, whereas in brick buildings any attenuation of signal strength is no more than a few decibels, the attenuation in steel-framed buildings can be of the order of 25 to 35 dB although this may reduce to about 15 dB if the aerial is located near a window and orientated for maximum signal.

Sky-Wave Propagation

Sky-wave propagation in the mf band is due principally to the reflection of the signal from the lower boundary of the E layer located at approximately 100 km above the surface of the earth. The various ionospheric layers including the E layer are formed by the action of ultra-violet radiation from the sun on the rarified gas at that altitude. The layers are composed, therefore, of free electrons, positive and negative ions, and non-ionised molecules in varying proportions. After dark, the ionisation in the E layer starts to decay, but the process is not complete and the layer retains a degree of ionisation throughout the night. Below the E layer is the D layer which is ionised during the day but which, because of its lower altitude, contains many more non-ionised molecules and totally disappears after dark.

When a radio wave arrives at the E layer it causes the free electrons to vibrate sinusoidally in sympathy with the electric field of the wave and with the maximum velocity of the electrons lagging the field by 90°. This results in the current flow due to the electron-motion being 180° out of phase with the current flow associated with a wave propagating through a dielectric. The effect of the electron-motion, therefore,

is to reduce the net current flow and this is equivalent to a reduction in the dielectric constant of the medium. As a wave approaches the ionised region it meets a layer of lower dielectric constant and so is reflected.

Moreover, within this region there are a few non ionised gas molecules, and whenever the electrons collide with these molecules energy is dissipated, thus causing some attenuation of the ionospheric wave.

During the night the effects as described represent the simplified behaviour of the E layer reflections, but in the day-time these reflections do not occur. Although during daylight hours there is a greater degree of ionisation in the E layer, the D layer also becomes ionised and, by virtue of the much greater number of gas molecules present, the energy loss due to excited electrons colliding with gas molecules is so great that the sky-wave is virtually eliminated altogether. The geometry of the sky-wave signal path is illustrated in Fig. 2. The mechanism is complicated by the earth's magnetic field which modifies the trajectory of the excited electrons in both the E and D layers. In general, the effect of a magnetic field is to cause any ray incident to an ionised region to split into two components, an ordinary ray and an extraordinary ray. For the medium-wave band the extraordinary ray is strongly attenuated, and the proportion of incident energy which appears as output in the ordinary ray is dependent upon the direction of the earth's magnetic field in relation to the direction of propagation and the direction of the electric vector of the incident wave. The main practical effect of this is that there is a considerably reduced sky-wave signal at night over east-west paths at lower latitudes. However, this effect, termed polarisation coupling loss, is insignificant at latitudes numerically greater than $\pm 45°$, and sky-wave calculations for paths within Europe need take no account of it.

The strength of the sky-wave signal starts to build-up around sunset and reaches a maximum approximately six hours later. This worst case is normally considered for planning purposes. Details of the calculation method used at the RABC Geneva 1975 followed current CCIR methods. However, because the method of calculation is based upon empirical relationships, and because the propagation phenomena in the mf band are dependent upon geographical location, it is perhaps not surprising that different calculation methods are favoured in different parts of the world. An attempt was made at RABC Part 1 to bring these methods together, and although this was not completely successful, arrangements to standardise on two basic methods were agreed.

For the Asian part of Region 3, north of latitude 11°S, the method is based upon 'Cairo North-South' statistical propagation curves[7]. For Region 1, which includes Europe, and also for Australia and New Zealand, contained within Region 3, the method proposed is described in ref. 8.

The basic equation to be used in Region 1 for the determination of sky-wave field strength due to 1kW radiated power at six hours after sunset is:

$$F = G - L + 105.3 - 20 \log p - 10^{-3}\, kp$$

where F = the annual median sky-wave field strength at 6 hours after sunset (dB rel. 1 μV/m)

G = a factor for sea gain (dB)

L = polarisation coupling loss (dB). This may be taken as zero in Europe

p = slant propagation distance (km)

and k = the basic ionospheric absorbtion loss factor (dB).

The significance of the term G (sea gain) is the fact that, when either the transmitting or receiving terminal is located in a region of higher than average ground conductivity, some enhancement of the sky-wave signal occurs. Conversely, where the local conductivity is low, a reduction in sky-wave signal strength occurs. For planning purposes, this is usually taken into account only when terminals are close to the sea and where, for oversea paths, or partially oversea paths, of 1500 km or more, the enhancement may be as much as 8 dB. As the distance from the coast to either the receiving or transmitting terminal is increased, so the effect of sea gain will decrease. Figure 3 shows the variation in sea gain with ground distance for various values of the distance between terminal and sea, measured along the propagation path.

The slant propagation distance p is indicated in Fig. 2. For ground distances in excess of 1000 km, ground and slant distances may, for practical purposes, be taken as numerically the same. For shorter distances, it is sufficiently accurate to assume

$$p = \sqrt{d^2 + 4h^2}$$

where d = ground distance (km)

and h = reflecting layer height which, for the E layer, is 100 km

The term for the basic ionospheric absorption loss factor, k, is quite complex and is given by:—

$$k = 1.9f^{0.15} + 0.24f^{0.4}\,(\tan^2\phi - \tan^2 37°)\ \text{dB}$$

where f = the frequency (kHz)

ϕ = the geomagnetic latitude. For propagation paths up to 3000 km this is calculated as the mean latitude of the transmitting and receiving terminals with reference to the earth's magnetic axis ($0 < \phi < 60°$).

Figure 4 shows the way in which this factor k varies with different values of ϕ.

In fact, without computer assistance, the above method of calculating sky-wave field strength is somewhat tedious, and for most engineering purposes it is sufficiently accurate to use curves such as those in Fig. 5. These curves have been calculated for specific frequencies and specific geomagnetic latitudes, and the sky-wave field strength in any given

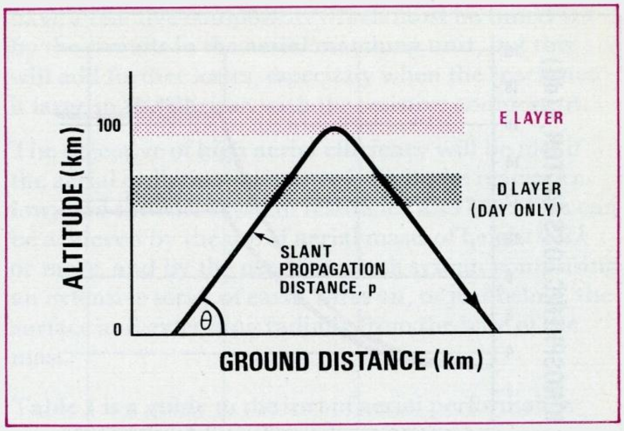

Fig. 2. The path of the sky-wave signal. Signals are reflected from the E layer after dark, but are highly attenuated in the D layer which is formed during the daylight hours. The slant propagation distance, p, is the total distance travelled by the sky-wave from transmitting aerial to receiving aerial via the E layer.

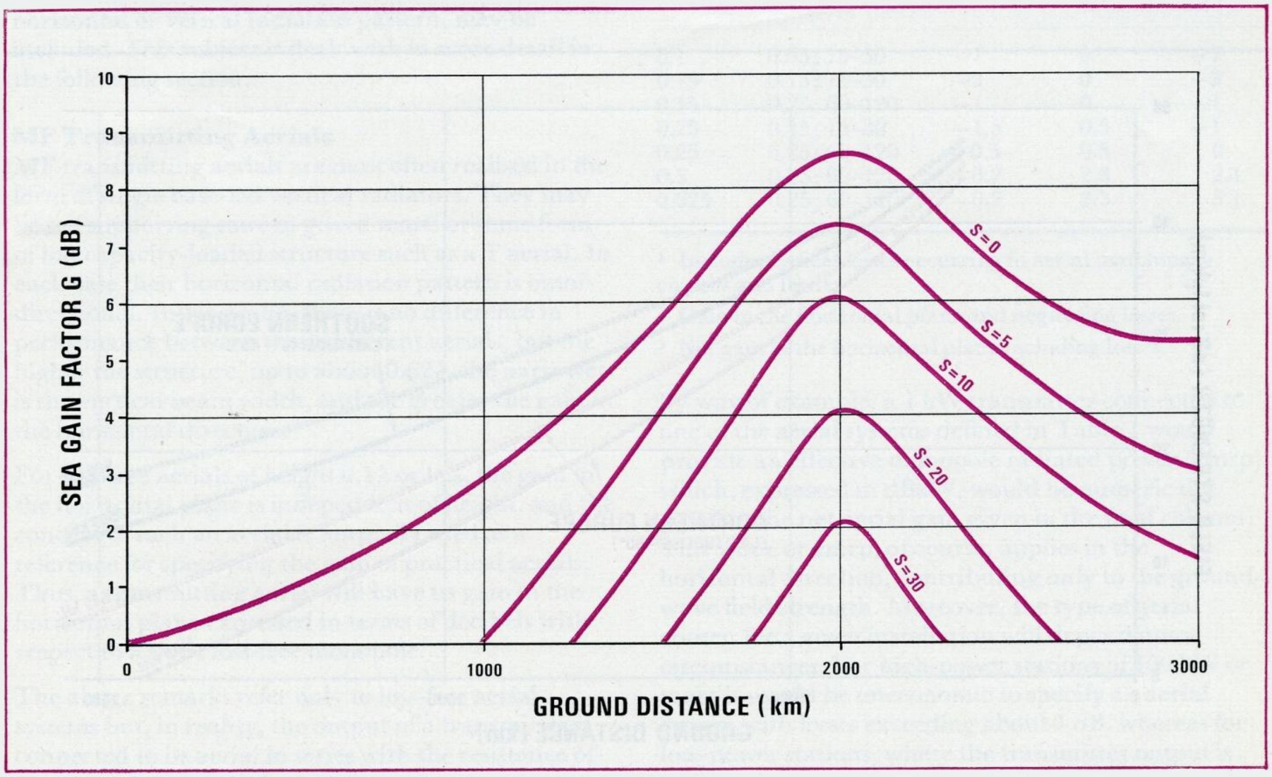

Fig. 3. Variation of sea gain with distance over sea, or mixed land/sea, paths for a frequency of 1000 kHz. Sea gain is the enhancement of the sky-wave signal due to the presence of salt water (having extremely high conductivity) near the transmitting and/or receiving terminals. The parameter, s, is the distance in km from either terminal to the sea, measured along the propagation path.

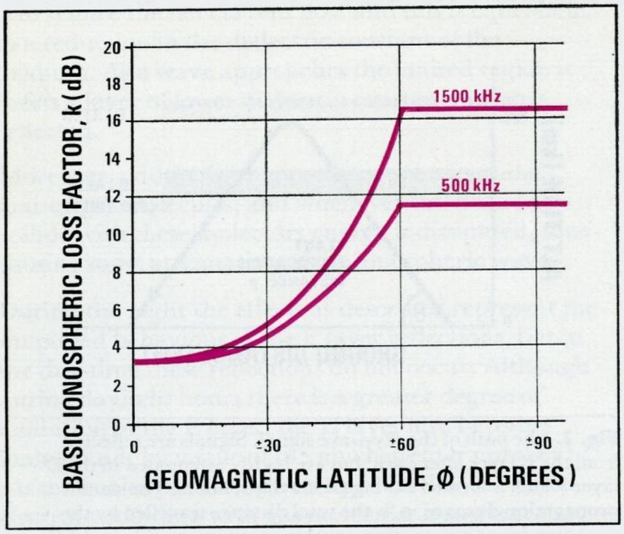

Fig. 4. Variation of basic ionospheric loss factor with geomagnetic latitude. The value given is the ionospheric loss per 1000 Km of sky-wave propagation distance measured along the slant path. Geomagnetic latitude is the mean latitude of the transmitter and receiver terminals with reference to the earth's magnetic axis.

case may be estimated by interpolation between the curves given.

The sky-wave field strength calculated by this method is the annual median value at six hours after sunset. The variations in field strength that occur at other times of the night are indicated in Fig. 6. It must be remembered, of course, that the sky-wave field strength may vary by 10 dB or more from minute to minute, and that there are also significant variations from one night to another. Any calculations performed on this basis, therefore, can represent no more than a general guide to the likely level of sky-wave signal.

It is to be noted that, so far, it has been assumed that the transmitting aerial radiates 1 kW semi-isotropically, i.e. equally and without loss in all directions along and above the surface of the earth. Where the transmitter power differs from 1 kW, this may, of course, be taken into account simply by changing the calculated field strength numerically by the same number of decibels as that by which the transmitter power differs from 1 kW. Similarly,

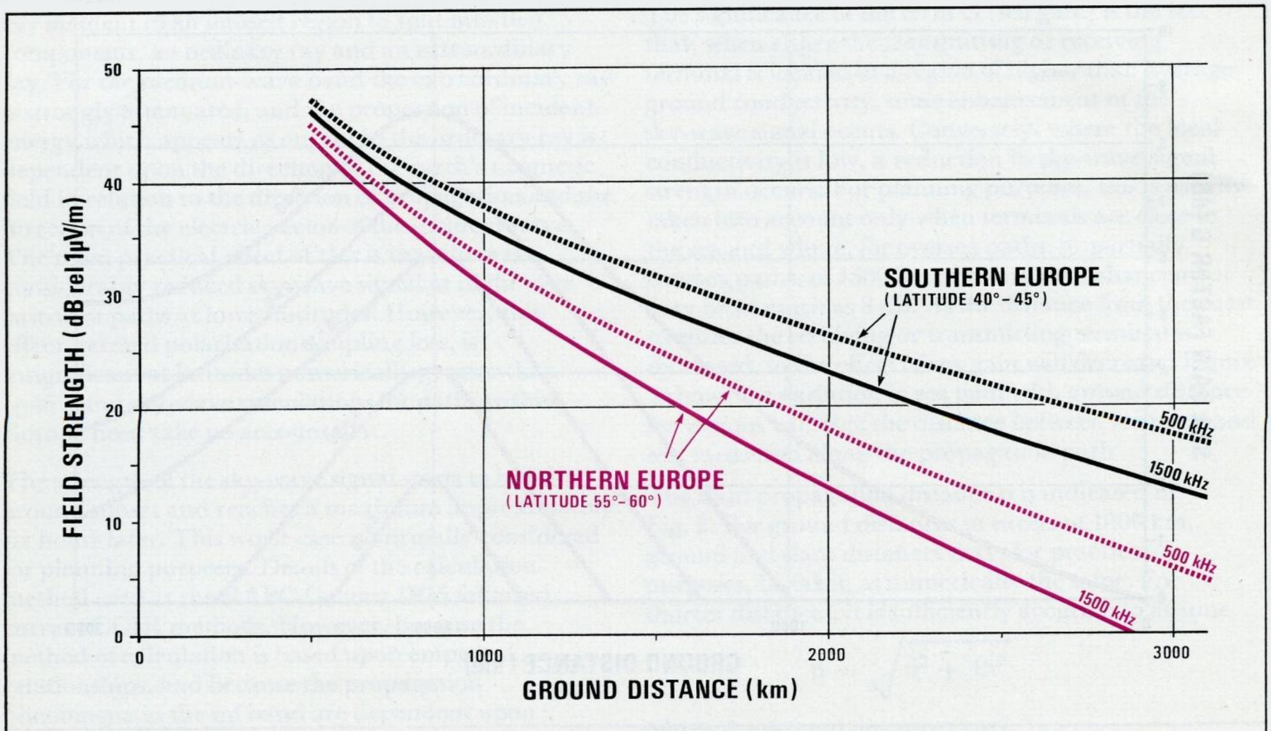

Fig. 5. Variation of sky-wave field strength with ground distance. The curves are in respect of a radiated power of 1 kW and give the annual median field strength at six hours after sunset. Use of such curves avoids the need for calculation of ionospheric absorption loss.

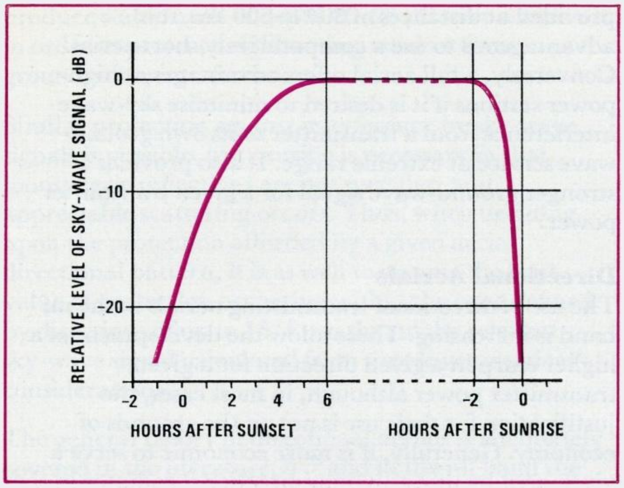

Fig. 6. Shows the way in which the sky-wave signal increases after sunset. It rises to a maximum about six hours after sunset and decreases rather more rapidly shortly before sunrise. The times of sunset and sunrise are taken as being appropriate to the centre of the path between transmitter and receiver.

transmitter aerial losses, and aerial gain due to horizontal or verical radiation pattern, may be included. This subject is dealt with in more detail in the following section.

MF Transmitting Aerials

MF transmitting aerials are most often realised in the form of single base-fed vertical radiators. They may be self supporting towers, guyed masts or some form of top capacity-loaded structure such as a T aerial. In each case their horizontal radiation pattern is omni-directional. Intrinsically, there is no difference in performance between these different aerials, but the higher the structure, up to about 0.62λ, the narrower is the vertical beam width, and the greater the gain in the horizontal direction.

For loss-free aerials of height 0.1λ or less, the gain in the horizontal plane is independent of height, and the concept of such an aerial is normally used as a reference for specifying the gain of practical aerials. Thus, a transmitting aerial will have its gain in the horizontal plane expressed in terms of decibels with respect to a short loss-free monopole.

The above remarks refer only to loss-free aerial systems but, in reality, the output of a transmitter is connected to its aerial in series with the resistance of the earth system. Efficiency is improved as the radiation resistance of the aerial is increased while the earth system resistance is reduced. The aerial will also have a reactive component which must be tuned out by the circuits in the aerial matching unit, but this will add further losses, especially when the reactance is large in comparison with the resistive component.

The objective of high aerial efficiency will be met if the aerial radiation resistance is high, the reactance low, and the earth system resistance also low. This can be achieved by the use of aerial masts of height 0.2λ or more, and by the use of an earth system comprising an extensive series of earth wires on, or just below, the surface and extending radially from the base of the mast.

Table 1 is a guide to the sort of aerial performance which is likely to be achieved on ground having a conductivity of 3 mS/m.

Table 1

MAST HEIGHT ($x\lambda$)	EARTH SYSTEM RADIUS ($x\lambda$); NO. OF WIRES	1 AERIAL EFFICIENCY (dB)	2 AERIAL GAIN DUE TO VRP (dB)	3 NET AERIAL GAIN (dB)
0.1	0.05; 15–30	−7	0	−7
0.15	0.15; 15–30	−3	0	−3
0.15	0.25; 60–120	−1	0	−1
0.25	0.15; 15–30	−1.5	0.5	−1
0.25	0.25; 60–120	−0.5	0.5	0
0.5	0.25; 60–120	−0.2	2.3	2.1
0.625	0.25; 60–120	−0.2	3.3	3.1

1 Includes typical losses occurring in aerial matching circuits and feeder

2 Gain in the horizontal plane and neglecting losses

3 Net gain in the horizontal plane including losses.

By way of example, a 1 kW transmitter connected to one of the aerial systems defined in Table 1 would provide an effective monopole radiated power (emrp) which, expressed in dBkW, would be numerically equal to the net aerial gain given in the final column. This value or emrp, of course, applies in the horizontal direction, contributing only to the ground-wave field strength. Moreover, the type of aerial chosen for a given installation will depend upon circumstances. For high-power stations of 100 kW or more it would be uneconomic to specify an aerial system with losses exceeding about 1 dB, whereas for low-power stations, where the transmitter output is 1 kW or less, it would generally be more economic to specify a simpler aerial system which may have losses of several decibels.

In calculating the strength of sky-wave signals it is necessary to take account of the vertical radiation pattern of the transmitting aerial. First, it is necessary to determine the elevation angle (ϕ in Fig. 2) in which the relevant sky-wave signal is radiated and, for this purpose, it is generally sufficient to assume that reflection occurs from the E layer at a height of 100 km above the earth's surface. Although F layer reflections may occur in certain cases, for most planning purposes the E layer reflections need be considered.

Figure 7 shows how the elevation angle of the sky-wave signal varies with distance. Because the vertical radiation pattern of the aerial is dependent upon its height, with taller structures providing narrower patterns in the vertical plane, it follows that there is a reduction in sky-wave signal when tall aerial masts are employed. Figure 7 illustrates this point also and shows that when the ground distance exceeds 1000 km the effect of aerial vertical radiation pattern is negligible, but for shorter distances, particularly below 500 km, the effect becomes more significant. It can be seen that, where a sky-wave service is to be provided at distances of 300 to 500 km, it is advantageous to use a comparatively short aerial. Conversely, a tall aerial offers advantages at high-power stations if it is desired to minimise sky-wave interference from a transmitter to its own ground-wave service at extreme range. It also provides a stronger ground-wave signal for a given transmitter power.

Directional Aerials

The use of directional transmitting aerials in the mf band is increasing. These allow the development of a higher emrp in a given direction for a given transmitter power although, in most cases, the justification for their use is not on the grounds of economy. Generally, it is more economic to serve a given area by using an omnidirectional radiator in the centre of that area rather than by means of a directional aerial located near the edge of the service area.

The main purpose in using directional aerials is to minimise interference to other, nearby, services operating on the same channel. It is possible to

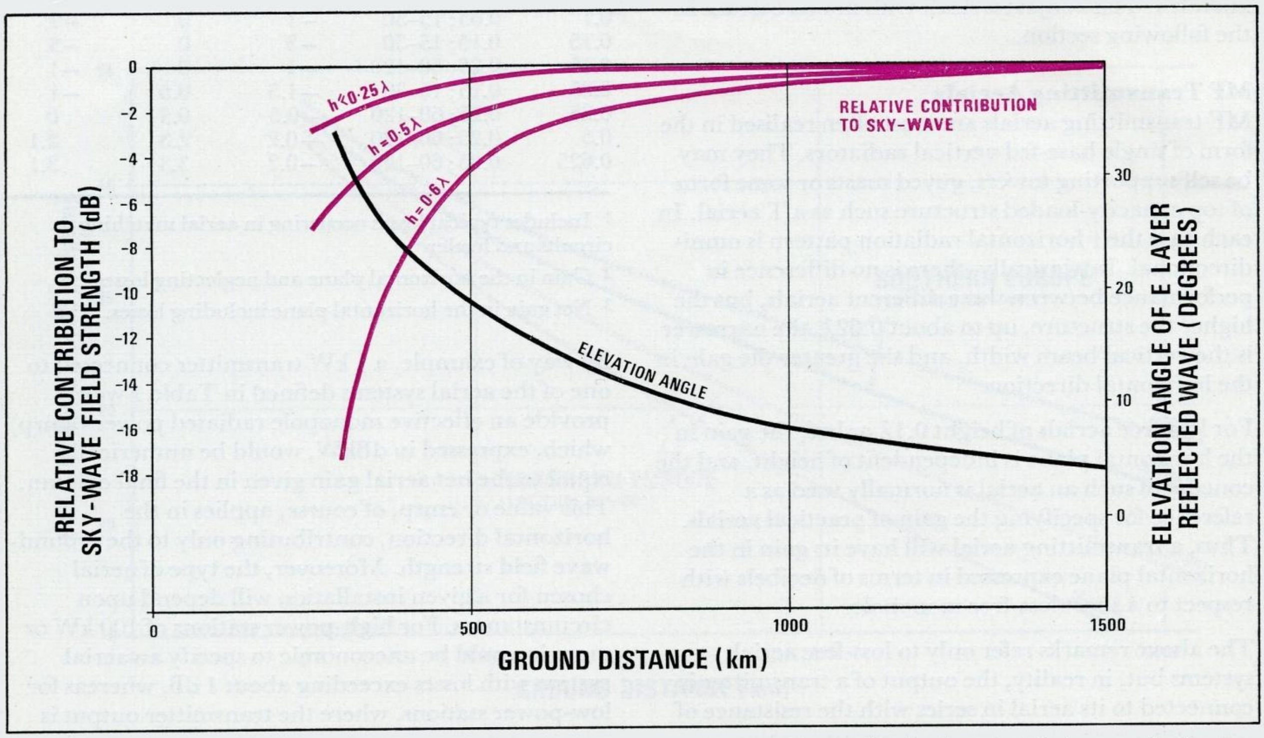

Fig. 7. Variation of elevation angle for E layer reflected wave with ground distance. The graphs also show the relative contribution to sky-wave field strength for transmitter aerials of various heights, h, and that taller aerial structures may be used to reduce sky-wave interference at distances of 500 km or less.

produce stable nulls of depth 20–25 dB over a wide arc in order to protect neighbouring services from ground-wave interference.

Similar protection against interference by sky-wave signals is possible, but caution is necessary in that ionospheric reflections are not specular, and appreciable scattering occurs. Thus, when deciding upon the protection afforded by a given aerial directional pattern, it is as well to assume the least value of protection occurring within the cone defined by directions of up to 15° from that of the relevant sky-wave signal calculated from simple geometrical considerations.

The general theory of directional aerials is adequately covered in the literature,[9, 10] and in the mf band the same general considerations apply as at higher frequencies where use of directional aerials is more usual. Directional patterns may be obtained by using a number of driven radiators, each fed with a specified proportion of the total signal and in a precise relative phase, or by the use of one or more driven radiators together with one or more parasite radiators. In practice, however, the close proximity to the elements of the imperfectly conducting ground creates design difficulties not normally experienced with aerials for higher frequencies. It follows that because of the need to design the aerial in such a way that local ground effects are minimised, and that seasonal effects do not alter the directional characteristics, very efficient earth systems are mandatory. A side effect of this is that directional aerials tend to be highly efficient and, typically a 4-element aerial might provide a gain of 6 dB in the main beam. Also, when such aerials are to be operated with high transmitter powers, additional difficulties are experienced in achieving sufficient long-term stability for any nulls that may be required in the radiation pattern. For all of these reasons, designing complex mf directional aerials requires specialised study.

The IBA network of local radio stations employs nine directional aerials of varying complexity[11]. Practical experience has shown that it is perfectly satisfactory for a channel to be re-used, both by day and by night, in a service area no more than 100 km distant from another station radiating 30 kW, provided that the aerials employed are well designed and engineered.

In order to illustrate the sort of pattern which is possible, Fig. 8 shows the measured pattern of the IBA aerial serving Manchester and using a frequency of 1151 kHz.

Planning Standards

There are two main factors which determine the standard of coverage at any given point in the service area of an mf transmitter. The first is the strength of the wanted signal in relation to natural or man-made noise; the second is the strength of the wanted signal in relation to interfering signals. The ratio of wanted to unwanted signals is referred to as the protection ratio and is normally expressed in decibels.[12, 13]

In practice, there are normally several sources of interference, and, in order to determine the overall effect, it is most convenient first to calculate the contribution to minimum useable field strength arising from each source. The overall value of minimum useable field strength is then calculated as the root of the sum of the squares (rss) of the individual contributions. This procedure is applied when the interference is steady, as during the day, and also when the interference fluctuates, as at night. In the latter case, and unless otherwise stated, the after dark minimum useable field strength refers to the annual median value at six hours after sunset.

In practice, noise limitation is likely to occur only by day because after dark, in most parts of the world, sky-wave interference will set the lower limit of useable field strength. The level of noise decreases with increase in frequency and, to a reasonable approximation, the following relationship applies

$$\text{Minimum value of field strength } (\mu V/m) = 1/f$$

where f=frequency in MHz.

Protection ratios have been chosen which allow a small degree of interference. They correspond, therefore, not with ideal reception conditions, but rather with a minimum reasonable standard bearing in mind the fact that the mf band is overcrowded. In general, the lowest protection ratio occurs at the edge of a service area, and there is a progressive improvement as one moves inwards towards the transmitter of the wanted service.

The required protection ratio for co-channel signals is dependent upon the programme material being transmitted both on the wanted and on the unwanted transmissions. The interference becomes more noticeable when the unwanted signal is compressed and the wanted signal contains what should be quiet passages. Use of compression on the wanted signal

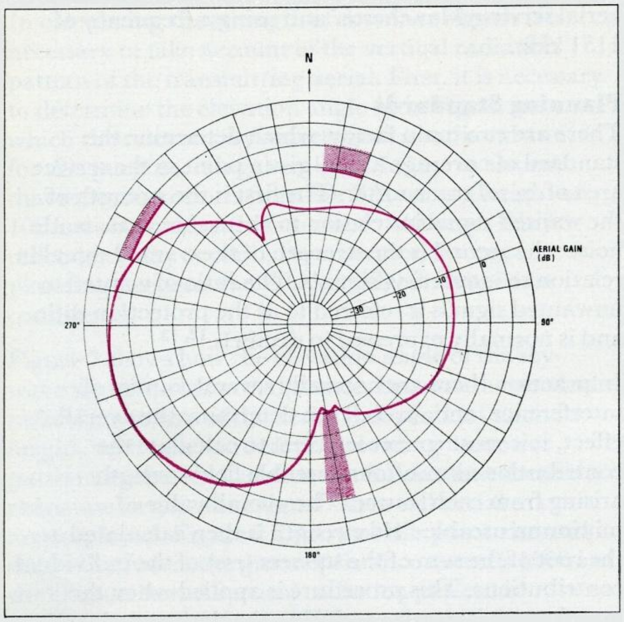

Fig. 8. The measured radiation pattern of a typical 4-mast radiator to be held in the IBA mf network. The gain is 6 dB in the main lobe and restrictions on the radiated power in certain directions to avoid interference with other services are shown. In order to meet these requirements, the aerial has had to be constructed assymetrically, i.e. the four radiators are not disposed along a straight line.

helps to reduce interference at the expense of quality. In the special case of a network of transmitters broadcasting the same programmes, it is possible to employ synchronised transmitters. This results in a substantial reduction in required protection ratio and allows more intensive use of any given channel. Synchronised operation of transmitters is discussed in more detail below.

Table 2

CO-CHANNEL PROTECTION RATIOS AGREED FOR PLANNING PURPOSES

CONDITION	PROTECTION RATIO (DB) FOR WANTED SIGNAL RECEIVED BY: GROUND-WAVE	SKY-WAVE
Between non-synchronised transmitters (i)	30	27
Between synchronised transmitters (ii)	8	8

(i) The above figures represent minimum values for planning purposes. In order to ensure imperceptible interference, the protection ratio would need to be about 10 dB greater.

(ii) Protection ratio required is dependent upon circumstances. See later.

As with co-channel interference, adjacent channel interference also is dependent upon the programme material, and on the use of compression on the wanted and unwanted transmissions. In addition, however, the bandwidth of the receiver and that of the unwanted transmissions are important. Thus, it is advantageous if those stations likely to cause adjacent channel interference operate with filters to limit the radiation to within about 5 kHz of the carrier frequency.

Table 3

ADJACENT-CHANNEL PROTECTION RATIOS AGREED FOR PLANNING PURPOSES

CONDITION		PROTECTION RATIO (DB) FOR WANTED SIGNAL RECEIVED BY:	
MODULATION COMPRESSION ON WANTED AND UNWANTED TRANSMISSIONS	APPROX. BAND-WIDTH OF UNWANTED TRANSMISSION (KHZ)	GROUND-WAVE	SKY-WAVE
Moderate	±10	9	6
Large	±10	7	4
Moderate	±5	5	2
Large	±5	1	−2

Where the wanted and unwanted transmission are separated by two channels, the required protection ratio is —23 dB.

Synchronised Transmitter Networks

The values for protection ratio given in Table 2 above show that the use of synchronised transmitters allows a considerably greater level of co-channel signal to be tolerated without causing excessive interference as compared with non-synchronised transmitters. It is clear, therefore, that the technique allows more intensive use to be made of any given channel.

To be effective, synchronised operation of transmitters requires that the difference between one carrier frequency and another be held to 0.1 Hz, or less, and that the modulation is the same for all transmitters in the synchronised group. The former condition prevents any noticeable beat occurring between carriers, and the latter ensures that the modulation of the unwanted transmission is not heard as a background to that of the wanted transmission.

Practical tests have shown that there is some advantage in controlling the frequency difference to within 0.02 Hz, and that this can serve to reduce the necessary protection ratio by a possible further 2 dB.

Tests have shown also that an advantage is to be gained by arranging for the modulation applied to each of the transmitters to be subject to the same time delay. By this means the interference does not appear as a leading or lagging echo, which can noticeably impair reception quality[14, 15]. In practice, the value of protection ratio needed may vary between 4 and 8 dB, the latter value providing a reasonably conservative basis that can be taken for planning purposes.

Low-Power Channels

Three channels (1485 kHz, 1584 kHz and 1602 kHz) were designated at the RABC as low-power channels (LPCs). Broadly, they are intended to replace the two international common frequencies which were features of the Copenhagen Convention, and the African Plan. When operating on any one of these channels the transmitter power must not exceed 1 kW.

The intention in introducing LPCs was to provide a number of channels on which low-power stations could operate with a minimum of co-ordination with other administrations. To that end, attempts were made to devise a special simplified co-ordination procedure, but in the event this could not be agreed and the procedure is somewhat cumbersome. It is required that the transmitter network in any one country be so regulated that the resultant field strength at the border of any neighbouring country, or at the mid-point of any intermediate overwater path, should not exceed 0.5 mV/m. Only stations within 500 km of the border, or the mid-point of an overwater path, would be included in the calculation of field strength. Departures from the 0.5 mV/m limit may, of course, be negotiated between the administrations concerned.

Modifications to the MF plan

A basic plan, agreed at the RABC in Geneva in 1975, is to come into effect on 23rd November 1978. It has been recognised, however, that it is impractical to attempt to forecast all future requirements for broadcasting services for the duration of the plan which is expected to remain in force until 1989. For this reason, procedures have been defined through which modifications may be made; these procedures may be invoked at any time either before or after the plan is brought into effect.

Article 4 of the Agreement is relevant in these circumstances. Broadly, it is required that the administration seeking the change shall obtain the agreement of all other administrations whose services may be affected by virtue of operating on the same or adjacent channels. In practice, this requires that the administration shall notify the International Frequency Registration Board (IFRB) of the proposed change to the plan, and shall state their assessment of the effect, if any, on the services of other administrations. The IFRB will then perform the necessary calculations in order to determine interference levels and will notify all those administrations concerned. Other administrations not identified in this way will have an opportunity of noting any changes likely to affect them from a weekly circular giving details of all such changes which is sent to all administrations.

The 1975 Geneva Plan differs from previous plans in that it defines a specific limit to the amount by which interference may be increased before it may be classified as unacceptable. This limit is agreed at 0.5 dB. Thus, the limit is given in terms of permitted change from that which exists, rather than an absolute level of field strength which must be protected to some given standard. While this is in some ways less than ideal, it does at least reflect a realistic approach, and it allows the practical situation to develop whereby interference levels may be higher in those parts of the world where the pressure for many services is greatest, and vice versa.

A feature of the Agreement is that additional sources of interference are allowed without limit although, in each case, the additional interference relates to a 0.5 dB increase over that existing when the assignment was first recorded in the Plan. Whenever further sources of interference are added, therefore, they will have progressively less and less incremental effect. It seems unlikely, in practice, that the cumulative effect of any new sources added during the life of the Plan will increase currently agreed interference levels by more than 1 or 2 dB.

In the case of modifications to assignments in the low-power channels, the administrations concerned should deal directly with any other administrations whose territory lies within a specified distance of the new or modified transmitter. These limiting distances are listed in Table 4.

Table 4

LIMITING DISTANCE FROM CO-ORDINATION OF CHANGES TO ASSIGNMENTS ON LOW-POWER CHANNELS

TRANSMITTER EMRP kW	LIMITING DISTANCE km LAND PATH	SEA PATH
1.0	600	600
0.5	400	400
0.1	70	250

Once the proposed changes have been agreed, the administration must then notify the IFRB accordingly.

It is to be noted, of course, that subsequent to the procedures quoted here, it is necessary for any administration intending to make a change to the plan to give notification under Article 9 of the present Radio Regulations.

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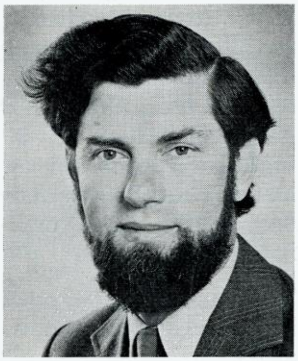


The Function of the Service Planning Engineer

by R J Byrne

Synopsis
This article gives the background against which the two following articles in this edition of *IBA Technical Review* are set and, at the same time, provides a general understanding of the role played by the service planner.

The development of a broadcasting network within the framework of basic national and regional plans, the aim of which is to provide a service to as much of the population as practicable, is discussed. Reference is made to both initial and detailed station planning involving frequency allocations, station siting, coverage prediction techniques, site testing and, finally, detailed measurement survey of coverage achieved.

Introduction

The successful development of a broadcasting service embraces a wide range of disciplines, but, so far as the viewer or listener is concerned, it is apparent only from the studio output. The overall system, however, is equally dependent on engineers having provided buildings, masts, aerials, transmitters and all the associated electronic equipment, and, of course, on the work of administrators. One particular and very essential activity on which the system depends is 'service planning', but because it does not directly result in tangible hardware it is frequently dismissed as being merely ancillary to the main stream of engineering endeavour.

The function of service planning will, naturally, vary from broadcaster to broadcaster. However, in the more technically advanced countries the service planning engineer will become closely involved at a number of stages. First of all, the provision of any broadcasting service is dependent on a carefully conceived overall plan, the initial stages of which follow from requirements broadly defined by the politicians and administrators. It is then necessary to formulate a detailed technical framework which will support the services to be provided, preferably on a regional rather than a purely national basis.

An obvious example is that of the 1961 Stockholm Plan[1] in which agreement was reached on the fundamental parameters for high-power 625-line uhf

television networks throughout what is termed the European Broadcasting Area. This plan stipulated, for approximate locations, the frequency allocations, maximum radiated power levels and maximum permitted mean effective aerial heights, for three- or four-channel coverage to co-exist throughout the Area within the frequency spectrum assigned to uhf broadcasting. It is shown basically in Fig. 1. The expertise of the service planner, through previous experience for part of Eastern Scotland of planning studies and by having participated in national and international Study Groups (e.g. EBU Working Parties or CCIR Study Groups), may have been instrumental in the deliberations which established the technical criteria, later to be utilised in evolving regional or area plans. However, it is in the implementing of detailed planning within the basic framework that the service planner comes into his own, by ensuring that maximum coverage to a satisfactory standard will be provided within the imposed economic and technical constraints.

Frequency Planning

The first requirement in the more detailed planning is to determine exactly where a service is needed. Obviously, if the service is to be an entirely new one, this presents no initial problem other than that of deciding which areas should be served first. However, as the network expands, close identification of all those areas requiring the service becomes increasingly complex until only a few per cent of overall population, scattered over the entire country, remain without service. The methods of defining and establishing these requirements will vary considerably between organisations. However, a separate article in this edition of *IBA Technical Review* explains the principles of field-strength surveying that may be carried out by the broadcaster.

Prior to the detailed planning of the high-power main stations, the frequency allocations and the limitations in radiated power etc. will have been already stipulated. The service planner then has to consider, initially by studying topographical maps, where the transmitter might most reasonably be located in order to provide maximum population coverage within the proposed area. At this stage it might become apparent that an unnecessary overlap between adjacent stations could be avoided if the full permitted power and/or mast height are not utilised. Figures 2 (a) – (c) illustrate the practical development of the Stockholm Plan for the area shown in Fig. 1.

In the extreme, particularly in more mountainous terrain, it might be found preferable, technically and economically, to provide two or three low-power stations, each of, say, 10 kW erp and having aerial heights of perhaps only 50 m, rather than a single high-power station of, say 100 kW erp or more, and an aerial height of perhaps 200 m. Such a case occurred in part of North-East Scotland and is shown in Fig. 2 (c).

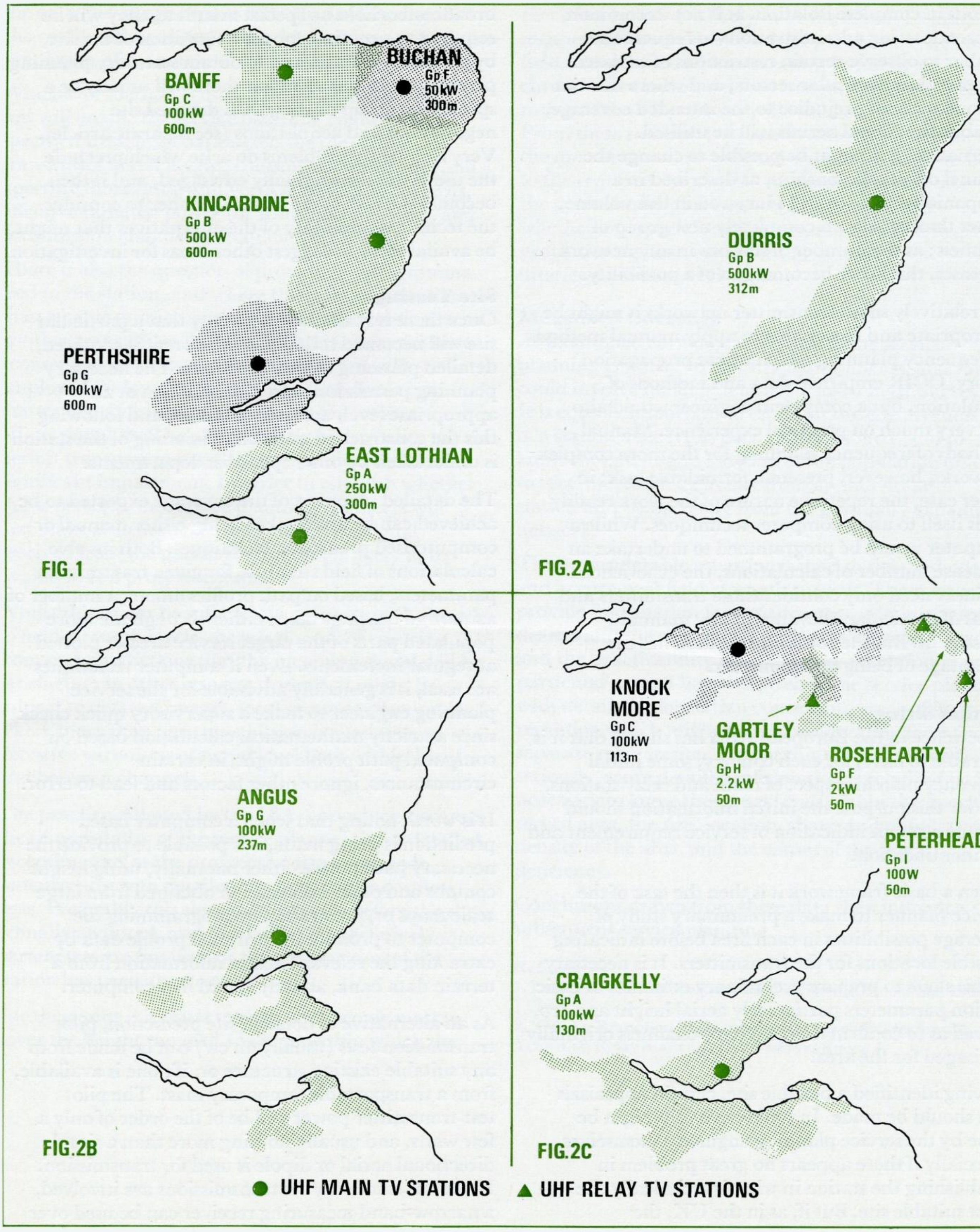
The planning of low-power fill-in relay stations is, in some ways, quite another matter, and it is far from true to suppose that the planning effort required for such stations is proportionally less than for main stations. In fact, quite the opposite can be true. Usually, the number of low-power relay stations greatly exceeds that of high-power main stations. For example, it is currently estimated that the uhf network in the United Kingdom will require 370 relay stations and about 51 main stations, providing a service to about 99% of the population.

Relay stations must utilise the same channels as those available to main stations, and to ensure that a number of relay stations such as 370 will neither suffer from, nor create, unacceptable levels of interference within their respective service areas is a complex exercise in frequency planning. Apart from national considerations, it is necessary for even the very low-power assignments to be co-ordinated internationally between the appropriate administrative bodies. Interference problems between neighbouring countries would become a serious problem if each country planned its transmitting

Fig. 1. Shows the 1961 European Area Stockholm Plan as applying to part of Eastern Scotland. Approximate service areas are shown for transmitters sited at assumed locations together with the uhf channel group allocations, maximum permitted ERPs and maximum effective aerial heights above mean terrain.

Figs. 2 (a), (b) and (c). The practical development of the Stockholm Plan for the area of Eastern Scotland shown in Fig. 1. The coverage achieved from the station locations finally selected, together with the uhf channel groups, ERPs and aerial heights above ground level may be compared with those permitted under the Stockholm Plan. The UK assigned station names are given.

It is sometimes unnecessary to utilise the full Stockholm assignments in respect of high-power main stations, and Fig. 2 (c) shows how, instead of the originally envisaged Stockholm provision of two main stations, Buchan and Banff, practical evaluation indicated that a better plan could be evolved by retaining only Buchan as a main station (Knockmore) and then completing the coverage of the area by providing a number of low-power relay stations.


BUCHAN
Gp F
50kW
300m
BANFF
Gp C
100kW
600m
KINCARDINE
Gp B
500kW
600m
PERTHSHIRE
Gp G
100kW
600m
EAST LOTHIAN
Gp A
250kW
300m
FIG.1
DURRIS
Gp B
500kW
312m
FIG.2A
ANGUS
Gp G
100kW
237m
FIG.2B
KNOCK
MORE
Gp C
100kW
113m
GARTLEY
MOOR
Gp H
2.2kW
50m
ROSEHEARTY
Gp F
2kW
50m
PETERHEAD
Gp I
100W
50m
CRAIGKELLY
Gp A
100kW
130m
FIG.2C
UHF MAIN TV STATIONS
UHF RELAY TV STATIONS

stations in complete isolation. It is not uncommon for broadcasting administrations to request one another to observe certain restrictions of radiated power within particular sectors, and where this can be done without prejudice to the intended coverage, suitable directional aerials will be utilised. Alternatively, it might be possible to change the channel offset relationships, as described in a companion article by A J Harwood in this volume, rather than to select a completely new group of channels; as the number of stations in any network increases, this latter becomes less of a possibility.

For relatively small transmitter networks it might be appropriate and reasonable to apply manual methods of frequency planning which utilise propagation theory, CCIR empirical data and methods of calculation, but a competent engineer would also rely very much on practical experience. Manual methods of frequency planning for the more complex networks, however, present a formidable task; in either case, the repetitive nature of the work readily lends itself to using computer techniques. While a computer would be programmed to undertake an immense number of calculations, the experienced engineer need only consider those transmitters and paths of particular relevance in any manual assessment. But the computer method has the advantage of being much quicker.

Station Siting

Experience in the European Area has shown that it is desirable to have, for each country, some initial frequency plan in respect of main and relay stations, and for this purpose the initial information should include a rough indication of service requirement and site identification.

Given a basic framework it is then the task of the service planner to make a preliminary study of coverage possibilities in each area before indicating possible locations for the transmitters. It is necessary at this stage to prepare preliminary estimates of basic station parameters particularly aerial height and erp, as well as to confirm the frequency channels originally envisaged for the area.

Having identified a possible site, certain appraisals of it should be made. In some cases this might be done by the service planning engineers themselves, especially if there appears no great problem in establishing the station in what is technically the most suitable site. But if, as in the UK, the broadcasters hold no special mandate, they will be required to negotiate for the acquisition of the site, by purchase or lease, and to obtain statutory planning permission. In this situation there will usually be a specialised group dealing with detailed site negotiations and acquisitions (see separate article). Very frequently problems do arise which preclude the use of the site originally envisaged, and it then becomes the task of the service planner to consider the technical suitability of the alternatives that might be available, or to suggest other areas for investigation.

Site Testing

Once there is reasonable certainty that a particular site will become available, but before it is acquired, detailed planning studies are made. The necessary planning permission, and authorisation at an appropriate level, are then obtained, and following this the construction and commissioning of the station is undertaken by other specialist departments.

The detailed planning of the coverage expected to be achieved can be undertaken using either manual or computerised prediction techniques. Both involve calculations of field strength, for given transmission parameters, based on path profiles among a number of azimuthal bearings taken either through the more populated parts of the target service area or plotted at regular increments. Even if computer techniques are used, it is generally advisable for the service planning engineer to make a supervisory quick check since a strictly mathematical calculation based on computed path profile might, in certain circumstances, ignore other factors and lead to error.

It is worth noting that when a computer based prediction is being made, it is possible to provide the necessary path profile either manually, using height contour and other information obtained from large scale maps or, preferably, by programming the computer to produce its own path profile data by extracting the relevant height information from a terrain data bank, already stored in a computer.

As an alternative to detailed site prediction, pilot transmission tests (usually on cw) can be made from any suitable existing structure or, if none is available, from a transportable temporary mast. The pilot test-transmitter power will be of the order of only a few watts, and usually nothing more than a simple directional aerial or dipole is used for transmission. However, since only cw transmissions are involved, a narrow-band measuring receiver can be used over

the entire coverage area as initially predicted, and the results extrapolated to produce a far more accurate prediction of coverage.

Whichever method is used, the prediction or site test will enable the service planning engineer to specify the essential parameters for the station, viz transmitter aerial height, transmitter aerial gain and aperture, horizontal and vertical radiation patterns, effective radiated power (or transmitter power), and transmission channel or frequency with offset.

There is also the question of providing a programme feed to the station, and where this is by means other than a cable or microwave link, direct reception from another transmitter is utilised. This is by far the most economical solution and is the method usually employed for low-power relay stations, but it is a matter of prime importance that the incoming off-air signal shall be of sufficiently high quality to permit transposition and re-transmission without significant impairment. In order to establish whether this is possible, the service planning engineers will first make a theoretical assessment of the signal received from the parent station that is likely to be available at a prospective site.

Whilst this might be sufficiently accurate with regard to field-strength levels, there is no way of ensuring from such predictions that the incoming signal will be satisfactory in other respects. Indeed, it might be subject to delayed images, local ground reflections or, where more than one transmission is available, to excessive variations of signal level both within band and between channels.

The practice adopted by the IBA, and which becomes the responsibility of the service planner, is for detailed reception tests at the prospective site to be made concurrently with detailed site predictions or pilot tests. Preferably this should all be done before the site is finally acquired, and also before the technical parameters are finalised or the construction of the station has been approved.

For these tests it is usual to erect a telescopic mast to cover the height range of 15–30 m within which the receiving aerials are likely to be mounted. Detailed measurements are then made of parameters such as field strength, sound/vision ratios, luminance/chrominance ratios, delayed images and overall K rating of the 2T pulse over the full height range[2]. From these results it is possible to ascertain whether the incoming and re-radiated signals are likely to be to the required standard. The results also indicate the optimum heights for receiving aerials, and whether any special requirements are needed to give protection against any potential source of interference should this exist.

Measured Coverage

As mentioned earlier, it is the task of the service planning engineer to identify requirements, and this could involve making detailed field-strength surveys. It is equally important to establish the effectiveness of a station once it has been commissioned, and to know the extent and location of the population able to receive a service directly from an individual station and compositely from the gradually expanding network.

Thus, considerable attention is paid to the methods and accuracy of field-strength surveys. These serve to provide information for broadcasters, administrators, dealers and the general public, of coverage achieved and the practicability of satisfactory reception in any particular area. They also provide the service planner with detailed information concerning areas of poor reception which might merit consideration for a separate relay station. But for this to be considered seriously, more detailed information is required. It is necessary to know the signal levels within the poorly served area, the size, location, shape and population density of the area, and the causes of the signal deficiency.

Conclusions drawn from these data then influence subsequent service planning.

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ANTHONY HARWOOD, C Eng., MIERE, was educated at Exmouth Grammar School, Devon. He afterwards joined the Operations and Maintenance Department of the BBC at Daventry in 1955. Four years later he moved to the United Kingdom Atomic Energy Authority at Aldermaston, Berkshire, where he was engaged with electronics as applied to Nuclear Physics, but in 1962 he returned to the BBC to work in the Planning and Installation Department on aerial systems and associated engineering.
After spending several months in the chemistry department of St. Andrews University, he gained further experience of aerial systems with two industrial organisations before joining the IBA in 1969 where he holds the position of Senior Engineer in the Network and Service Planning Department. His extra mural activities include playing the bassoon in an amateur orchestra and collecting vintage wireless equipment.

Technical Constraints in Service Area Planning

by A J Harwood

Synopsis
Technical constraints on the planning of television services in the United Kingdom are imposed by geographical considerations and the limited availability of channels. There exists, therefore, the possibility of interference between services in different areas, but this may be avoided by careful siting of stations and choice of channels allocated to them.

The problems that have to be considered include those caused by different stations using the same channel, and the likelihood of mutual interference occurring between existing and proposed services. In this latter case domestic receivers may be a contributing factor.

Geographical features can have a marked effect on the siting of transmitting stations, particularly low-power relays, and have a strong influence on the provision of programme feeds. Again, careful siting enables better channel utilisation.

Introduction

The principal objective in planning a television service is that it should be available to the maximum number of viewers. Naturally, this must be achieved within certain constraints, both administrative, financial and technical, and it is these latter which are the subject of this article.

The technical constraints can be divided into three categories; those imposed by the limited number of channels available, those attributable to topography and those imposed by the need to provide a programme feed to each transmitting station. To some extent all of them are interdependent. Within the UK, there is the further complication that television service planning is carried out on the basis that each uhf station shall be capable of radiating up to four programmes (only three of which have so far been allocated), and so embrace the services provided

by both the IBA and the BBC. There is, therefore, a high order of technical co-operation between service planning engineers in the two organisations.

Channel Allocation

The bandwidth of a television channel as specified for System I is 8 MHz, the vision carrier being 1.25 MHz above the lower edge of the channel, and the sound carrier 6 MHz above the vision carrier. In the United Kingdom and the European area, uhf broadcasting makes use of 14 channels in Band IV, and 30 in Band V. In the United Kingdom specifically these 44 channels have been divided into nine standard groups which, wherever possible, are assigned to the various transmitting stations, where, in each case, four of the channels in each group are allocated one to each programme. Additionally, it is sometimes necessary to use non-standard groups of channels. The possibility of utilising a particular channel group at a given transmitter location depends on two factors, namely, whether the group would be susceptible to interference from some other station, or whether it would be likely to cause interference in some other service area.

For purposes of planning, the permissible level of interference is taken as that which produces an average impairment of grade 3–3.5, or worse, on the EBU 6-point scale for not more than 5% of the time within the service area, or for not more than 1% of the time on a re-broadcast link (RBL) (see Television Programme Technical Quality Assessments and Reporting Procedure, *IBA Technical Review 2*). Although co-channel interference is the major factor precluding the use of any particular group of channels, there are others. These include the nearby use of upper or lower adjacent channels, also those likely to interact in some way with existing services in neighbouring areas, i.e. those channels which would either cause, or suffer from, image interference, and those which could give rise to problems of radiation from receiver local oscillators, see Fig. 1.

Co-Channel Interference

Any television set which simultaneously receives a wanted and an unwanted signal will, if the unwanted signal be of sufficient level, display a picture on which is superimposed a pattern resulting from an interaction between the two incoming signals. In the particular case where the two signals occupy the same channel, the effect is termed co-channel interference. It has been determined that, for picture degradation of grade 3, if the two vision carriers are within ± 500 Hz of each other, then the level of the unwanted signal, measured at vision carrier, should be 45 dB below that of the wanted signal at the receiver input.

Since the subjective effect of the patterns produced by this interference is related to the line structure of the picture, it is possible for these interference patterns to be made less objectionable by offsetting the frequency of one carrier with respect to the other by an amount related to the line repetition frequency. In the UK where a frequency offset of 5/3 line frequency ± 500 Hz is used, the level of unwanted signal that can be tolerated rises to 30 dB below that of the wanted signal.[1] In this way, moreover, three choices of vision carrier frequencies become possible, i.e. V_c, $V_c + 5/3$ line frequency, and $V_c - 5/3$ line frequency. Use of offset working, thus, enables higher levels of co-channel signals to be tolerated. Hence the distance between planned co-channel stations may be decreased, and the channels used more extensively by taking advantage of the different offset conditions. But there is, of course, a penalty to be paid in that greater attention must be given to carrier frequency stability.

Protected Field Strength

If a receiving aerial is orientated towards a wanted station, and an unwanted signal is also present, then the relative level of the unwanted signal at the receiver input will depend on the aerial directivity, and on whether the two signals are similarly or orthogonally polarised. At any given location it is possible to determine the highest field strength likely to be encountered from the unwanted signal for a stated percentage of the time, and the resulting level of unwanted input at the receiver. Therefore, in order that the wanted signal shall produce a picture that is not unduly impaired, it must produce an input signal level that is higher than this by either 30 or 45 dB depending on whether or not the respective carriers are offset. The field strength necessary from the wanted station for producing this level of signal is known as the protected field strength for the stated percentage of time, and it may be one of the parameters that defines a service area.

The choice and type of receiving aerial used by members of the viewing public is outside the direct control of the broadcasters. Hence, calculations of co-channel interference likely to be experienced within service areas have always to be made on the basis of an average domestic aerial installation.

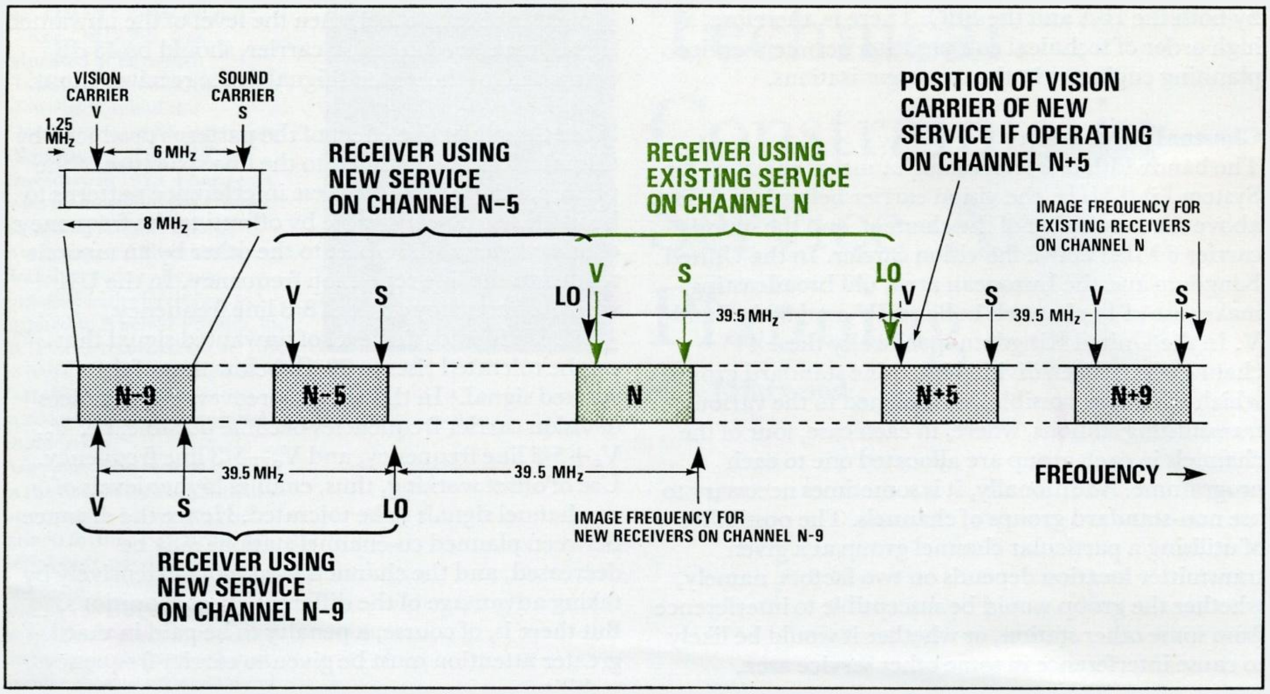

Fig. 1. In selecting channels for a new television service consideration has to be given to those already in use in nearby areas. Because of the possibility of interference being caused by the use of superheterodyne receivers, either to the old service or the new, the use of certain channels is precluded. Local oscillators in most receivers operate at a frequency of 39.5 MHz above the vision carrier of the incoming signal. Hence, if channel N is used by a neighbouring service, the choice of channel N+5 for the proposed new service would result in interference being caused from local oscillators in existing receivers. Alternatively, the use of N−5 for the new service would be likely to result in interference into the existing service area from local oscillators in new receivers.
Similarly, channels N+9 and N−9 should be avoided from the point of view of image interference.

However, when providing re-broadcast links at transmitting stations, it is sometimes necessary to accept field strengths which would not be adequately protected were relatively simple receiving aerials to be used. In such cases recourse has to be taken to using more elaborate aerials having extra directivity. An extreme case is at Alderney, in the Channel Islands, where a specially designed adaptive aerial is currently being brought into use. In this case, there are several interfering signals which are sensed by an active circuit. This, then automatically causes the reception pattern of the aerial to be altered in such a way as to minimise their contribution to input voltage.

Adjacent Channel and other Interference

Any receiver sensitive to an adjacent channel signal in the presence of a wanted signal will also display visual interference, the nature of which will depend on whether the upper or lower adjacent channel is present. For System I, the protection required at the aerial input of domestic receivers is 9 dB against the lower adjacent channel, where the principle cause of trouble is the interfering sound carrier, but only 3 dB against the upper channel, because in this case the interfering signal is further removed from the wanted vision carrier.[1] Hence, for domestic viewing, the level of adjacent channel signals that can be tolerated within a service area are higher than those for co-channel interference.

Re-broadcast links between stations operating on adjacent channels are usually avoided as they involve the use of additional and costly filters. In future, however, it is possible that adjacent channel transposition might become more practical for low-power relay stations.

Other interference problems result from the use of superheterodyne receivers, and if a relay station is to serve an area close to an existing service, such effects must be considered. Standard receiver practice is for the vision intermediate frequency to be 39.5 MHz, with the local oscillator frequency above the vision

carrier of the incoming signal. Suppose the existing channel is N, then local oscillators in existing receivers will be operating on a frequency which falls within channel $N+5$, hence this would obviously not be a wise choice of channel for the new service. Similarly, were the new service to operate on channel $N-5$, local oscillators in the new receivers could cause interference within the existing service area. In fact, this problem is reducing with the move toward receivers incorporating solid-state tuners. With these, oscillator radiation is significantly less than with valve receivers.

There would also be a problem with the use of channel $N+9$, which would be the image frequency for existing receivers, or of channel $N-9$, which would have the existing channel as its image.
The constraints imposed upon channel utilisation in an area close to an existing service are summarised diagrammatically in Fig. 1, and the arrangement of the nine standard channel groups is shown in Fig.2.

The Effects of Topography

Local topography has a double effect on service planning in that it influences where the population settle and affects the propagation of electromagnetic waves. The first effect, being an historical fact, has to be accepted. The second can be circumvented and, in some instances, utilised to advantage.

As explained elsewhere, the uhf television network in the UK will eventually comprise 51 main stations, supplemented by about 370 relays. The purpose of the main stations within any area is to provide coverage to the major part of the population living within that area, the limits of service being defined by the levels of field strength, co-channel interference or ghosting. All three of these are affected by the topography, and it might even be the cause of significant numbers of population living in certain locations within the area being left without a service.

In order to rectify this situation, it may be necessary to build one or more relay stations. The siting of these is

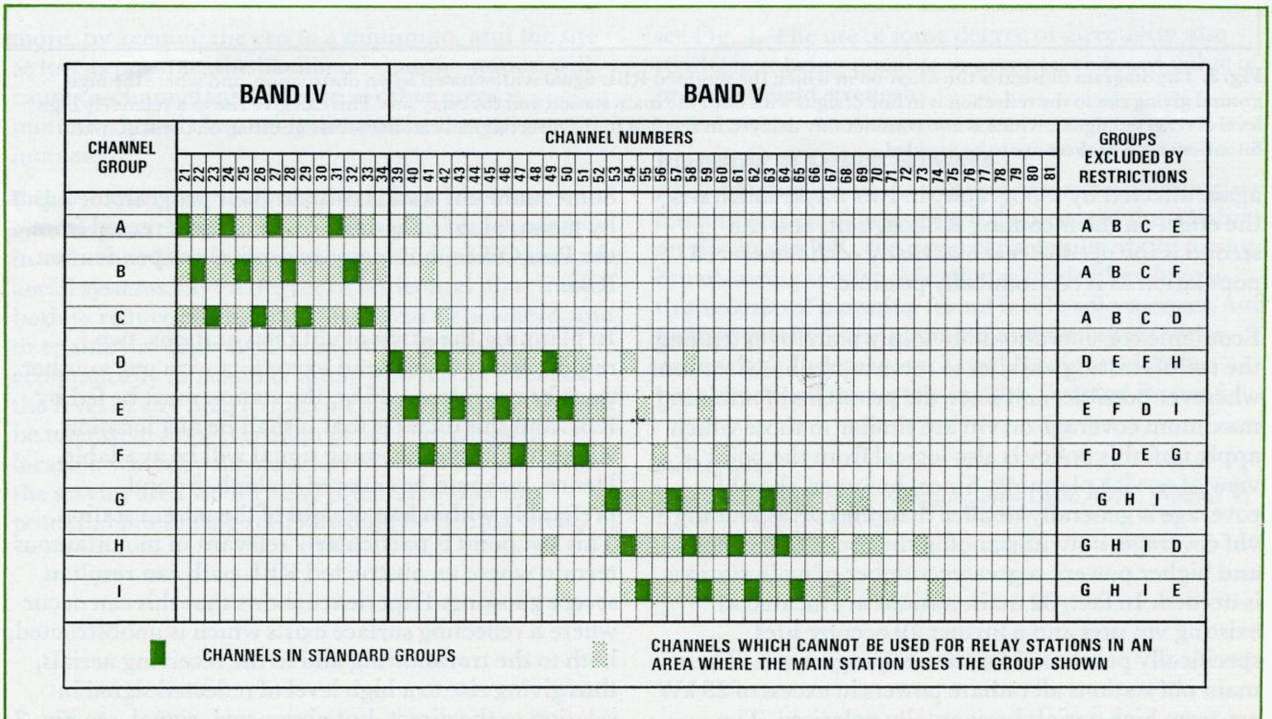

Fig. 2. There are in all 44 channels in Bands IV and V which are available for television broadcasting. They have been arranged in nine standard groups as shown, and in each group four channels are assigned one to each of the programmes ITV, BBC1, BBC2, and a fourth programme as yet unallocated. The diagram also illustrates those channels which cannot be used for relay stations in situations where a given group is already in use at a nearby main station.

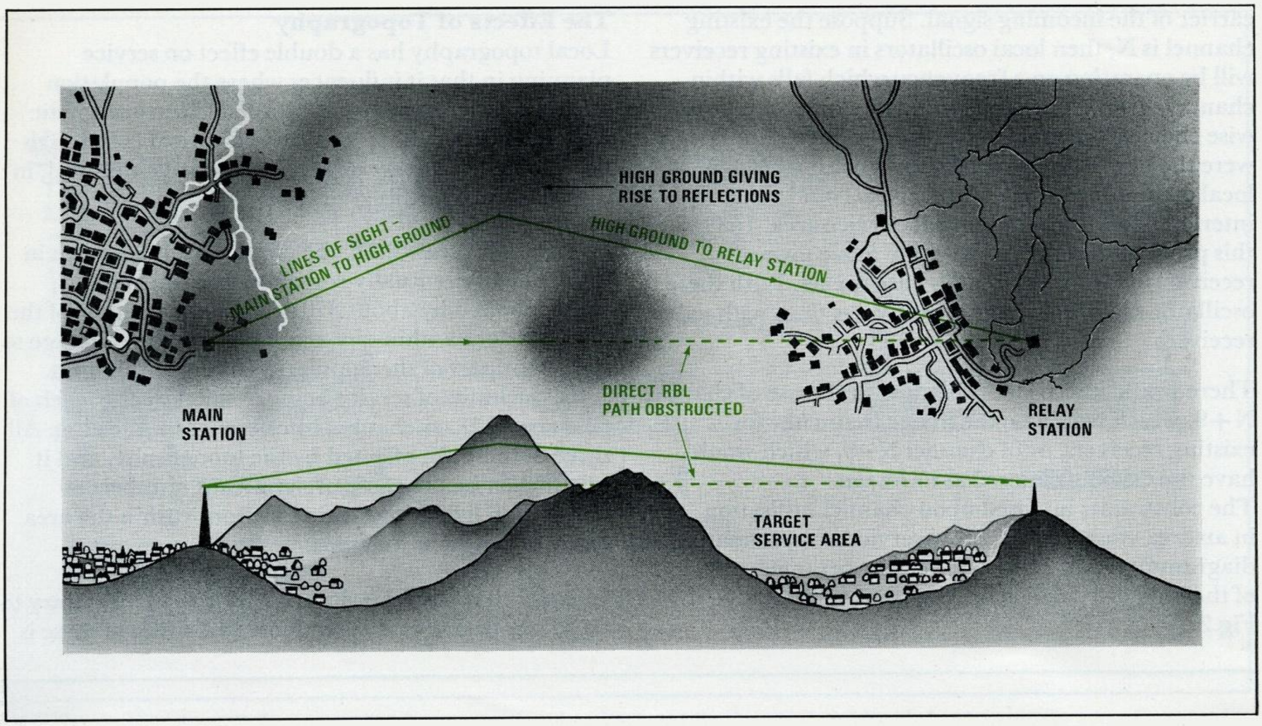

Fig. 3. The diagram illustrates the situation in which the required RBL signal is attenuated by an obstruction, and where the high ground giving rise to the reflection is in line of sight with both the main station and the relay site. This can give rise to a relatively high level of reflected signal, which is also considerably delayed in relation to the direct signal, causing severe ghosting on the RBL path. Situations such as these are to be avoided.

again affected by topography in two ways; the first is the effect on the incoming RBL signals, and the second is the need to reach as many of the unserved population as is economically possible.

Economic considerations obviously point to extending the use of existing vhf sites to serve as main uhf stations wherever possible, and since the problems of attaining maximum coverage on vhf are similar to those which apply uhf, this policy is also logical from the point of view of service planning. Since, however, the uhf coverage is generally smaller than the corresponding vhf coverage, notwithstanding the use of taller masts and higher powers, a greater number of main stations is needed. In fact, 32 main stations are located at existing vhf sites and a further 19 occupy sites specifically purchased for the uhf programme. These main uhf stations all radiate powers in excess of 25 kW erp from high aerials horizontally polarised. The horizontal radiation patterns are mainly omni-directional, although at a few stations the erp in certain directions is deliberately restricted in order to reduce co-channel interference elsewhere.

Some main uhf stations obtain their programme input by means of shf links or by other circuits rented from the Post Office, but many are entirely dependent on RBL.

In planning the siting of uhf relay stations, two requirements which tend to conflict with one another must be considered. First, the station must be fed by RBL and this dictates that it shall be at a location where a suitable incoming signal will be available. Hence, it should be situated on high ground, preferably within line of sight of the parent station. This last point is particularly relevant in mountainous terrain where an obstructed RBL path can result in severe ghosting. Experience shows that this can occur where a reflecting surface exists which is unobstructed, both to the transmitting and to the receiving aerials, thus giving rise to a high level of reflected signal in relation to the direct, but obstructed, signal, see Fig. 3. Second, from the point of view of effective coverage, the selected site should be as close to the target service area as possible, since this can reduce the power required, and hence the cost of the station. Further-

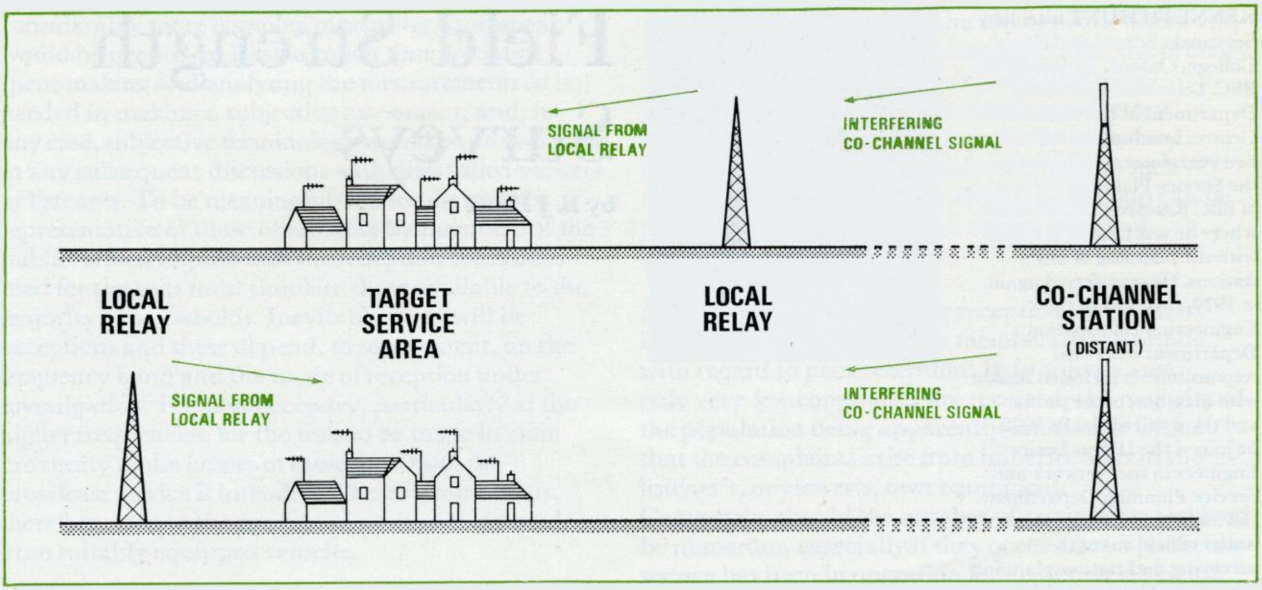

Fig. 4. Correct siting of a relay station can minimise the effects of co-channel interference from the existing service. A relay station site, as in the top illustration, does not allow any aerial discrimination between the wanted and unwanted signals. A better arrangement is shown in the lower diagram. In this case a higher level of co-channel signal can be tolerated.

more, by keeping the erp to a minimum, and the site as low as possible, the likelihood that the station will cause co-channel interference in other areas is minimised, and channel utilisation is, thereby, increased.

Relay stations use vertical polarisation, to afford greater protection to the viewer against co-channel interference from main stations, and, in most cases, the aerial systems have a degree of horizontal directivity both to reduce co-channel interference elsewhere, and to enable the desired coverage to be achieved as economically as possible. Siting also has an effect on the level of any interfering co-channel signals that can be tolerated, since it is often possible to choose a location whereby the majority of receiving aerials in the service area would be so orientated that the potential interfering station would be behind them, see Fig. 4. The use of some degree of directivity also results in it being possible to accept a reduced value of protected field strength.

Planning of Other Services

Although the above description of service planning has a strong emphasis toward the needs of the 625-line service in the UK, the general principles apply to any broadcasting service. Mention is made elsewhere in this volume of planning for mf local radio services, and further details of the planning and setting up of the Authority's Independent Local Radio services has been described separately in *IBA Technical Review 5*.

References

1. CCIR XIIth Plenary Assembly, New Delhi, 1970, Volume V, Recommendation 418–2.

KENNETH HUNT attended Sevenoaks School and New College, Oxford. He joined the BBC Television Recording Department at the Television Centre, London, in 1962 and two years later transferred to the Service Planning Section of BBC Research Department where he was mainly involved with the planning of uhf stations. He transferred again in 1970, this time to the Engineering Information Department where his responsibilities included liaison with members of the public and the retail trade. In 1972 he joined the IBA as Senior Engineer in the Network and Service Planning Department. His main activity at present is that of field strength surveying and station planning in respect of both television and local radio services. He is married, has two sons, and lives in Hampshire.

Field Strength Surveys

by K J Hunt

Synopsis

The reasons for making field strength surveys and the methods applied in the case of different services using different frequency bands are considered. The case of the uhf 625-line television service is described in detail since, in the UK at present, this is the subject of most of the field strength survey work being undertaken. In any given area survey information is built up over a period of time, several years in many cases, as each new transmitter in neighbouring areas is brought into service. Any remaining deficiency in that area may then constitute a requirement for a relay station, and the service provided by this relay when it comes into operation, will also need to be surveyed.

Surveying is an integral part of service planning, and examples are given which show how, in a given area, the results of different surveys made at different times interrelate one with another.

Introduction

This article is an attempt to answer some of the many fundamental questions which could be asked about this subject. The word 'attempt' is chosen deliberately because the answers may be applicable to only one organisation, and at one particular time. Although the fundamental principles are essentially unchanging, their application must reflect the varying technology both of the 'professional' installations at the transmission end of the system, and also the consumer equipment at the receiving end. Hence, it can be said that reception surveys represent an attempt to evaluate the effects of the transmission medium on the signals radiated by broadcasting organisations in order to distribute programmes. The electromagnetic radiation used for this purpose covers a range of frequencies extending, in the case of services provided by the IBA, from the medium frequency (mf) band (531 to 1602 kHz plus the sidebands of the two end channels, as stipulated at the 1975 Regional Area Broadcasting Conference in Geneva) to the ultra high frequency (uhf) band (470 to 854 MHz). In all cases it is considered that the end product must be viewers, or listeners, who are satisfied with the technical quality of their reception, and the aim of a survey is to determine the extent to which this objective has been achieved. This necessitates both objective measurements and subjective assessments though it is likely that, in many cases, the latter could be eliminated by an extension of the former. However, there would be several penalties;

considerably more complex measuring equipment would be needed, at least as much time would be spent making and analysing the measurements as is needed in making a subjective assessment, and, in any case, subjective terminology would be unavoidable in any subsequent discussions with dissatisfied viewers or listeners. To be meaningful, the results must be representative of those obtainable by members of the public, which implies that the reception conditions used for the tests must simulate those available to the majority of households. Inevitably there will be exceptions and these depend, to some extent, on the frequency band and the mode of reception under investigation. It is also necessary, particularly at the higher frequencies, for the tests to be made in close proximity to the homes of those for whom the broadcast service is intended. These requirements, therefore, lead to the concept of surveys being made from suitably equipped vehicles.

In a correctly planned network, the power which a particular transmitter may radiate is constrained by lower and upper bounds set, respectively, by the conflicting requirements of providing enough signal within its planned service area while not causing interference outside that area. Propagation factors affect these requirements in that interference levels will, in general, vary either because of ionospheric effects at lower frequencies, or atmospheric effects at the higher frequencies. The results of these variations will not be further considered here, except to remark that planning must proceed on the basis that protection against interference can be achieved only for a specified percentage of the time. Thus, one purpose of a survey is to verify that a transmitter is achieving its desired service coverage while using the minimum power.

Service Area

The concept of a service area might need some explanation, especially as the requirements of the IBA for television are somewhat different from those for radio. For radio, each of the current ILR stations is planned to serve a discrete urban area, or group of urban areas, and each programme company is associated with a single service area. If there are overlaps between stations the programme companies involved are competing for the same audience. This competitive element also applies to television programme company overlaps, yet within each programme company's area there will be many unavoidable overlaps between stations. This is especially so in the case of the uhf network where very many stations are involved. In these cases, the primary object of a survey must be to ensure that those previously without a service receive satisfactory signals, the overlap area being of only secondary importance. For the local radio services, no such relaxation of measurement within the overlap can be permitted; the whole of each service area is of importance.

A further reason for making reception surveys is to investigate complaints from members of the public with regard to poor reception. If, in a given area, only very few complaints are received, the majority of the population being apparently satisfied, it is likely that the complaints arise from imperfections in the listener's, or viewer's, own equipment.
Conversely, should the number of complaints received be numerous, especially if they occur after a particular service has been in operation for an appreciable time, the cause is likely to be either the propagation path, or the transmitting equipment. If transmitter malfunction can be ruled out, effects such as the recent erection of tower cranes, oil rigs, pylons or new buildings must be considered. A reception survey can then determine the cause and indicate possible remedies. In an extreme case, it might be necessary to plan for a new relay station.

Both the equipment and technique of a survey depend on the transmission frequency, and whether it is in respect of radio or television. In all cases, a measuring receiver for the appropriate frequency band is needed, as is a radio or television receiver for the subjective assessments. Suitable receiving aerials are also required and these are of Yagi or log-periodic structure except for the mf band where a loop aerial is used. Directional aerials are used for providing gain (relative to simple structures) and also to provide adequate rejection of unwanted signals. Such signals can be delayed versions of the wanted signal resulting from reflections, or they can be signals from other transmissions. In the case of mf, no such precautions need be taken because the majority of receiver aerials in use have a directional pattern similar to that of a loop aerial, and therefore undesirable channel relationships must be avoided as completely as possible in the planning stage, at least for the daytime service. Most external domestic aerials are roof mounted and so provision must be made to elevate the test aerial to a comparable height above the ground. By international convention, a

height of 10 m is adopted. For mf, however, the screening effects of houses and other buildings are irrelevant, and a hand-held receiver with a built-in aerial may be used near ground level.

The question then arises as to which locations should be chosen for making measurements. Several different approaches to this problem have been investigated. Choosing locations at random, or according to some fixed geometrical grid pattern, would eventually provide all the information needed, but would entail much wasted effort, and an enormous volume of results would require analysis. It has been found preferable to attack the problem on two fronts. First, an examination of map data before measurements commence will provide an indication of areas where local screening by topographical features might cause reception problems, or limit the extent of the service area. Second, detailed measurements around each deficiency, whether predicted or encountered as work progresses, will enable its extent to be determined. Thus the aim is to concentrate on those areas where difficulties are likely to arise, and to obtain only limited information about others. Provided that the measurement density, i.e. the number of measured locations per square kilometre or per thousand people, is related to the potential difficulty of reception, it can be reasonably assumed that all deficiencies in excess of a specified size will be found.

The uhf television network provides a good example of the way in which requirements vary with time. When a network is being built priority is given to provide a service in the major centres of population. Next, smaller areas are dealt with, and the general tendency is for later stations to be progressively smaller. The information required from surveys varies similarly. Initially, when stations serving between several hundred thousand and several million people are brought into service, the surveys must identify the reception deficiencies affecting up to tens of thousands of viewers in order that the next generation of relay stations might rectify these deficiencies. At a later stage it becomes possible to adopt a technique using a higher measurement density so that much smaller deficiencies of, say, one hundred people can be identified. This might at first appear to involve unnecessary repetition of measurements in an area, but a network is not built up in a contiguous fashion. Many of the smaller deficiencies left by early stations may be partially or wholly served by later stations, even though such provision may not have been predicted. To plan and build relay stations in such instances would be costly, and wasteful of channels. The aim of early surveys, therefore, should be to identify deficiencies and give an approximate idea of the area and population involved. Then, as the network builds up, the surveys should become more detailed and opportunity can be taken to refine measurements made earlier.

Eventually, when deficiencies containing one thousand people, or less, are being considered, it becomes possible to match the relay service as closely as possible to the required area. Only by so doing is it possible to re-use channels at relatively close distances and thus achieve a composite coverage closely approaching 100%. However, it is not possible to contemplate making many measurements per thousand people until the planning for the network nears completion.

The Procedure

Because the nature of the uhf frequency band is such that large variations of signal level and picture quality can occur with relatively small changes of location, uhf television surveys will be considered as an illustration of the procedure. Lower frequency bands are treated in a similar manner but, in most cases, with a lower measurement density.

In order to place survey technique on a quantitative basis, it is necessary to work to pre-determined standards. Ultimately, these are related to the degree of acceptability of various forms of picture degradation, and the EBU six-point impairment scale is used for quantification. This and other similar scales are fully described in *IBA Technical Review 2*, but for convenience the impairment scale is quoted here.

Impairment	Grade
Imperceptible	1
Just perceptible	2
Definitely perceptible but not disturbing	3
Somewhat objectionable	4
Definitely objectionable	5
Signal unusable	6

Picture assessment in terms of grade is taken as the mean of a large number of observations, and in survey work an average grade of 3.5 or less is regarded as acceptable. In the greater part of a service area a grade of 1 to 2 would be achieved, and only on the edges of definite deficiencies would it be expected to drop to

3.5. The impairment can result from a number of causes, the most common being noise, delayed image signals ('ghosts') and interference from other transmissions. Of these, the second is primarily a function of the local topography around any particular receiving location. It is thus outside the control of the broadcaster except in the sense that, at least when considering small areas, the siting of relay stations should be such as to avoid, as far as possible, transmission paths which are obstructed. This also conserves transmitter power.

Noise and interference are both within the control of the broadcaster and may be considered at the planning stage by assuming the use of a receiving system with a specified maximum noise factor and minimum directivity. By this means a minimum receiving aerial gain can be specified for achieving satisfactory results at the edge of a service area. Because viewers may use aerials of widely differing type and manufacture, the minimum signal level required in the service area, i.e. that which is commensurate with a noise impairment of grade 3.5 using a receiving aerial of modest gain, is defined in terms of field strength. The field strength is the emf between two points one metre apart, in free space, in the plane of the electric component of the electromagnetic radiation. To measure field strength it is necessary to use a system of known gain which is achieved by careful selection of equipment backed by a calibration procedure.

The factors to be considered are aerial gain, feeder loss and receiver sensitivity; and the stability of all three is important. That of the aerial can be assured by using relatively simple and rugged construction, and by periodically checking the gain under controlled conditions by means of a substitution method. Feeder loss and receiver sensitivity are both checked in the laboratory against standard signal sources and power references prior to each survey. Receiver stability may be ascertained from a calibration source having a stability at least an order of magnitude better than that of the receiver itself. Such a source should be included as part of the survey equipment. Provided that the robust feeder used remains undamaged, it is sufficiently stable, but in view of the continued flexing to which it is subjected, a policy of replacement at regular intervals is followed even when no visible damage is evident. The overall accuracy should be within 0.5 dB.

The same receiving aerial and feeder are used both for the measuring and for the subjective assessment. This poses obvious problems at the fringes of service areas where the relatively low field strength combined with a low aerial gain, imposed by size and weight considerations implicit in a rugged structure, could cause pictures to appear more degraded by noise than would be the case for a domestic installation using a high-gain aerial. To some extent the use of a relatively short feeder of low loss provides compensation, but special exercises involving comparison of performance between the two situations, domestic and vehicle, have shown that results, on average, are very similar. This would not be so if low-noise, masthead pre-amplifiers were in widespread domestic use unless such a device were likewise used in the vehicle installation.

Computer Techniques

As in many other activities, computer-aided techniques are being introduced into survey work, primarily in connection with mapping the results of completed surveys, and it is also convenient to arrange that the method used for recording the results is such as to permit easy entry of those results into a computer. The form shown in Fig. 1 is an example, and this is generally used in conjunction with a map. This type of form enables common items, such as transmitter number, to be entered only once. It also allows for a number of items of information to be entered against each measurement location which is cross referred to the map by a unique number. An alternative approach would be to record the National Grid Reference for each location, but this would be time consuming and error-prone, and it is better achieved by using a digitising device at a later stage. At each location, provision is made for recording the field strength and three types of impairment (noise, delayed image signals, co-channel interference) for each of the three channels currently being transmitted. All three are recorded because the IBA and the BBC share survey information and each organisation is responsible for surveying those stations for which it is the landlord, i.e. half the total. In this way, much duplication of effort is avoided, and although the techniques employed by the two organisations are not identical in all respects, they are sufficiently similar to allow results to be interchanged reliably and without conflict either of interest or of technical standards.

These measurements and assessments represent the average result for each of the three channels at any

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POINT No	V F/S	S F/S	CH No N	G	C	V F/S	S F/S	CH No N	G	C	V F/S	S F/S	CH No N	G	C	REPRESENTATIVE F/S	N	G	C	REMARKS
6	13	16	b	b	b	26		b	b	b	39	42	b	b	b	52	b	b	b	
90	90					90					87				2	89				CH 28 LOW POWER
91	85					86					84				2	85				
92	85					84					80				2	84				
93	78					78					72				3	77				
94	85					85					83				3	84				
95	79					80					78				3	79				
96	75					75					70				3	74				
97	64		3			66		3			60		4		3	63	3			50 NEW HOUSES
98	54		5			52		5			43		6		6	49				UNINHABITED
99	84					84					78				2	83				

V VISION
S SOUND
F/S FIELD STRENGTH
N NOISE
G GHOSTING
C CO-CHANNEL INTERFERENCE

Fig. 1. An example of the form used for recording results obtained during field strength surveys. In addition to recording the results in respect of the individual channels at any location, in dB, it is useful to stipulate a single figure representing reception performance, notwithstanding the fact that some variation will almost certainly exist between the present three services.

location. This is necessary because significant variations of field strength and impairment grade can occur if an aerial is moved even by only a few wavelengths, and in the case of the uhf band, this distance is merely one or two metres. In particular, the vector addition of the direct signal and a reflection from a nearby object, or from the ground, can cause a decrease of field strength of, typically, 6 to 10 dB and this loss may be recovered by a small positional movement of the aerial. The method used for deriving the average is only quasi-scientific and relies on the judgement of skilled operators, but has the major advantage of providing a very rapid result. It simply requires the vehicle to be moved slowly, with the aerial elevated to 10 m, over a distance of up to 5 m, which is about equal to that available for aerial positioning on most roof tops. During the movement of the vehicle, the measuring engineer can assess picture quality and field strength, and record 'typical' values. The whole process is repeated for each of the other two channels. However, if the field strength noted when the aerial is first elevated is sufficiently high, the averaging procedure is superfluous.

It is desirable to have for each location a single figure to represent the reception performance in respect of all the present three services. This is usually the worst of the several results obtained. At most locations, inter-channel differences will be small and can be logged without further measurement. But at those locations where a large standing-wave pattern of field strength is found, it is necessary to ensure that all three channels can be received with a single aerial at a fixed point, and this can involve a rather more extended period of measurement. A 'remarks' column provided on the form is useful for explaining apparently anomalous results due, for example, to trees, which may not be marked on the map but are virtually opaque at uhf, and can cause a significant reduction of field strength in an otherwise uniformly served area. The 'remarks' column can also be used for recording the presence of new housing developments which so often are situated in locations where propagation difficulties exist, or for noting periods during which transmitters are operating on reduced power so that the results can be adjusted as appropriate.

The choice of each measurement location and associated measurement density are based on results previously obtained. In this way most of the effort can

be devoted to those areas where a good service is potentially most difficult. Although problems are encountered as the survey progresses, such as areas where there is a high level of delayed image signal which require extra attention, the general principle adopted is that in areas of very high or very low field strength, say 10 dB on either side of the nominal, only about five locations per square kilometre of populated area are measured. The nominal level referred to can vary, but in the absence of co-channel interference it is taken as being 64 dB and 70 dB for Bands IV and V respectively, both figures being relative to $1 \mu V/m$. In areas of high field strength, the worst locations are chosen to ensure that any potential difficulties are examined; in areas of low field strength, the best locations are measured in order to establish the service boundaries. Some 'line of sight' areas well removed from the main service area, if not already served by another transmitter, may also be examined.

In areas where the field strength is within 5 or 6 dB above or below the nominal limit, the measurement density rises to a value of at least 25 locations per square kilometre. This is the value that has been established by experiment as being necessary for reproducible assessment of an area where a service deficiency is of the order of a hundred people.

Service Area Contours

It is convenient, using a map, to show the served and unserved areas as being separated by means of a line, but it must be emphasised that, because of the variation of field strength and picture quality over relatively small distances, this cannot be regarded as an absolute limit. Rather, it is a guide for subsequent analysis, and this can include measurements of other, 'neighbouring' transmitters which might, in fact, adequately serve the areas found to be deficient of signals from the local transmitter. As mentioned earlier, this is of special importance in those cases where the adjacent transmitters have been operational for some years and were originally surveyed at a much lower measurement density. When all the measurements have been completed, the results must be processed and presented in an easily usable form both for planning purposes, and as a guide to dealers and the public about the service area of the station. Some of this work has already been computerised, and it seems likely that this trend will continue.

An example of the results obtained during a survey has already been given in Fig. 1. Examples are also given which illustrate the changing pattern of surveys during the past 10 years, and the way in which information about a particular unserved area has been built up and used in defining a relay station requirement. This relay station, which is eventually constructed and commissioned, is then the subject of a further survey, and the results of this are also shown. The area which is the subject of this example is that part of Luton shown in Figs. 2 to 6. For normal use the survey results are computer processed and plotted onto a transparency which can be placed over the associated Ordnance Survey map. The use of a computer enables the same set of results and contours to be used in conjunction with a variety of map scales without the need for manual scaling and this, incidentally, makes for simplicity when publishing results obtained. The maps shown in Figs. 2–6 were produced by transferring symbols from a computer-drawn overlay onto a print of a map.

Figure 2 shows the measured coverage from the Oxford transmitter. To facilitate rapid visual assessment of results, coded symbols are used. Each distinct symbol represents a 5 dB range of field strength except at the extremes, e.g. a triangle is used to indicate the range from 70–75 dB relative to $1 \mu V/m$. Although the Crystal Palace service was measured before Oxford, it was re-surveyed after the transmitting aerial had been changed and it is these results that are given in Fig. 3. An increase in the measurement density, and thus in the survey detail, can be seen, and the shape of the deficiency has been defined more closely. These results, in conjunction with others obtained in the area north of London, were used in determining the siting of the transmitter which was subsequently built at Sandy Heath.

The results of surveying Sandy Heath in Luton are given in Fig. 4 which shows a further considerable increase in measurement density. At this stage, the shape of the uhf network having been clearly defined, all subsequent survey work used a similar order of measurement density to ensure that results will remain valid until at least the end of the present construction phase which provides relay stations, where practical, for serving residual deficiencies of more than 1,000 people. In the event, it has been found that no significant change will be necessary to provide for the proposal to extend coverage to those deficiencies containing between 500 and 1000 people which was recently considered by the Crawford Committee

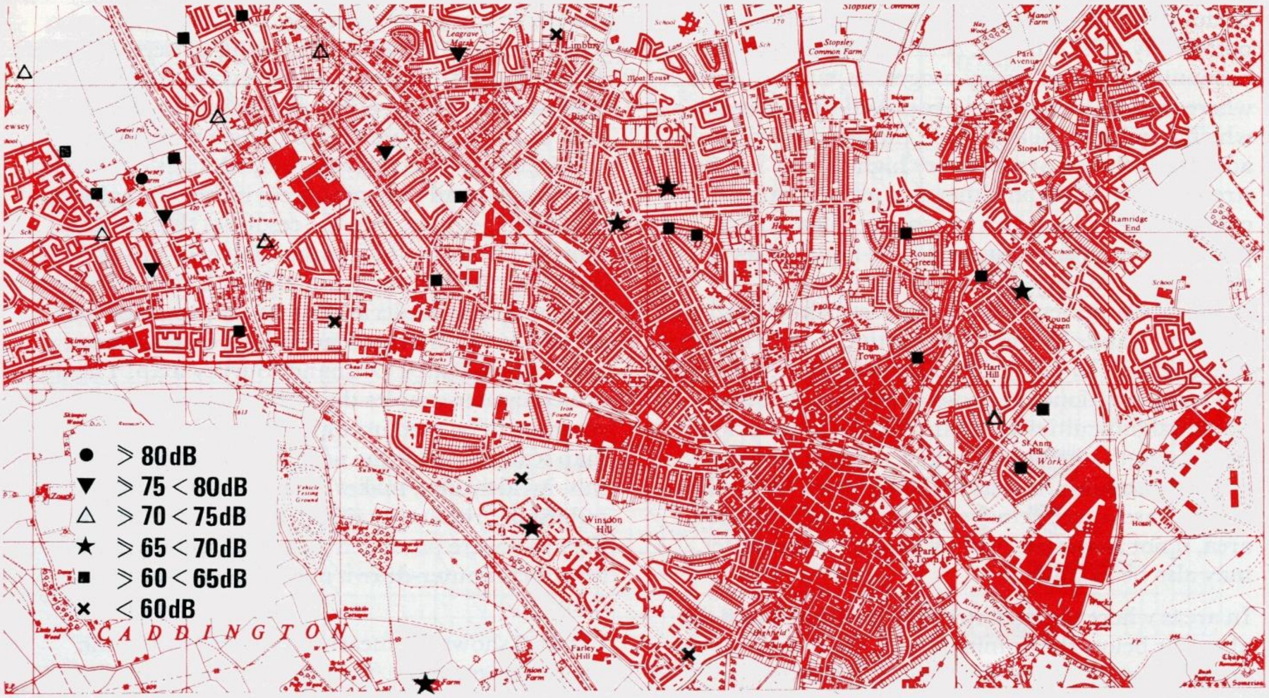


Fig. 2. Coverage in Luton from the Oxford transmitter. No measurements were made in areas which, from a consideration of the topography, were expected to be unserved. Symbols used to represent field strength values on survey maps have been chose to make possible a rapid visual assessment without the need to read individual numbers.

Fig. 3. Coverage in Luton from the Crystal Palace transmitter. These measurements were made later than those shown in Fig. 2 and more detail had been found to be necessary.

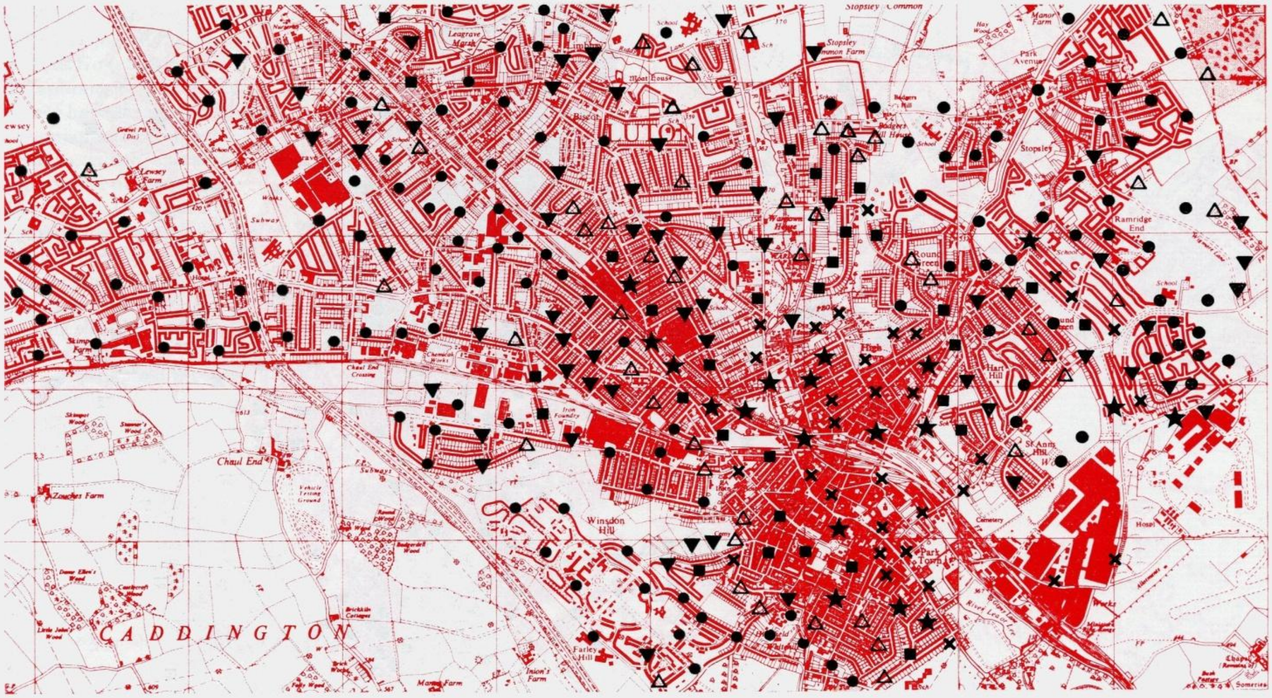


Fig. 4. Coverage in Luton from the Sandy Heath transmitter. Considerable detail was needed to define the target area for the Luton relay.

Fig. 5. The area shown uncoloured was the target service area for the Luton relay station. Although not apparently very large, the area contains about 20,000 people.

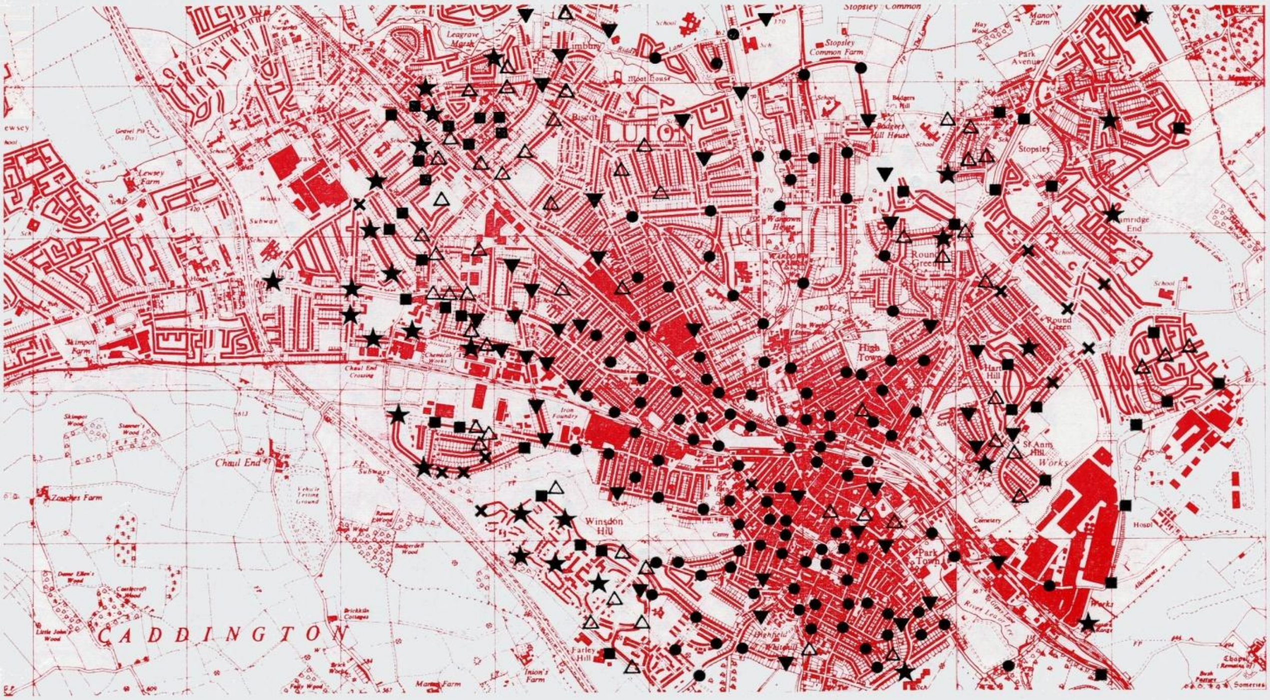


Fig. 6. Coverage of the Luton relay station. It can be seen that in order to be certain of providing a minimum standard of coverage to all of the target area, it is necessary to provide a service covering a much larger area.

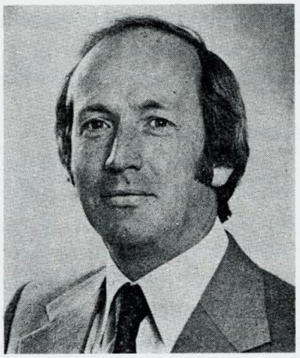
and is currently being further considered by the Committee on the Future of Broadcasting under the chairmanship of Lord Annan, which is expected to report during 1977.

Because of composite result of Figs. 2 to 4 cannot easily be seen, Fig. 5 shows the residual deficiency forming the requirement for the Luton relay station. This has now been built and the results of surveying it are shown in Fig. 6. These results taken in 1975 complete the cycle which commenced with the early measurements of Crystal Palace in 1965.

In other areas a similar cycle continues. It might have a shorter or a longer time-scale than was the case for Luton, but the desired overall objective is to provide a service to more than 99% of the population of the UK by the early 1980's. At around that time the existing 405-line vhf television network is likely to be phased out and it is possible that the channels so released may be used for additional 625-line colour television services. Perhaps a new cycle of surveys will then be required and the whole process start all over again.

Figures 2—6 in this article are based upon Ordnance Survey maps with the sanction of the Controller HMSO. Crown Copyright Reserved.

BRIAN SALKELD, C Eng, MIERE, joined the Authority in 1962 from Standard Telephones & Cables Ltd. where he had spent six years commissioning transmission systems, mostly overseas microwave networks. Previously, he worked on armaments research for the Ministry of Supply, and on missile guidance systems with the Plessey Co. Ltd. Since joining the Authority he has been engaged in network provisioning, and his early work centred on the development of re-broadcast receivers for feeding microwave links. He was appointed Head of Network Planning in 1974.



Planning Microwave Links for Television

by B Salkeld

Synopsis
Microwave links are used for extending the IBA television transmitter network in situations where re-broadcast links are impractical. For example, with the need to re-use the available uhf broadcasting frequencies many times over, the level of co-channel interference sometimes prevents re-broadcasting at a site which is otherwise suitable for covering an unserved area. It then becomes necessary to introduce a microwave link from a point of good reception.

This article describes the factors that must be considered in planning television links, and outlines the survey methods used. The overall system design for re-broadcast links and the derivation of the television specification for shf equipment are also discussed, and some critical features of equipment design are indicated.

Introduction

The UK Independent Television uhf network links together fourteen programme company regions, each with one or two main transmitters. Network switching centres operated by the Post Office ensure that any company's programme can be routed to any or all transmitters in the country.

The network connecting the major population centres is composed mainly of microwave radio links rented from the Post Office. A total route distance of about 5,500 miles interconnects sixteen main transmitters which together serve approximately 70% of UK population. Service is extended to the remaining areas by means of further transmitters and transposers which are fed by re-broadcasting the outputs of the main regional transmitters. Re-broadcasting in this way requires that a strong signal free from interference, is available at the site of the relay transmitter or transposer station. In general, the planning criterion is that the wanted signal shall be of such strength that any noise or interference present shall remain within acceptable limits for 99% of the time. The limiting factor is usually interference from another station on the same channel, i.e. co-channel interference (cci).

Where it is impractical to use re-broadcast reception at a proposed transmitter site, microwave links are used for extending the programme from a point of good reception. Occasionally it becomes necessary to use microwave all the way from the parent transmitter to the relay, but more often it is possible to extend the programme from a point of good reception. This is illustrated in Fig. 1. Re-broadcast links (RBLs) of this type cover a route distance of about 1,000 miles.

Frequency Planning

Subject to Post Office agreement, licences for frequency allocations in respect of private microwave systems are issued by the Home Office together with a specification with which all private systems must comply. The purpose of the specification is to enable

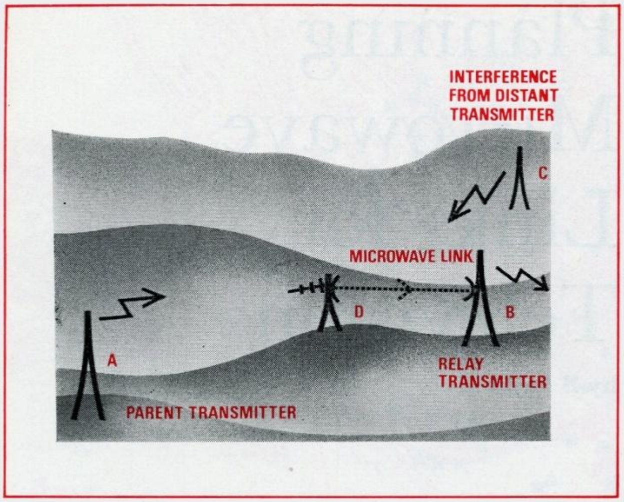


Fig. 1. National uhf television coverage in the United Kingdom requires that the available frequency channels be used many times over. The extent to which this can be done is limited by the level of co-channel interference that can be tolerated in any situation. In the example shown here, re-broadcast reception at transmitter B would suffer unacceptable interference from the distant transmitter C should this be co-channel with the main station A. Interposing a microwave link from a point of good reception D enables the programme service to be extended and the problems of co-channel interference avoided.

numerous private users to operate without mutual interference in the restricted frequency band of 7.1–7.9 GHz. Transmitted power is limited to 10 kW erp and aerial performance must result in a 55 dB front/back ratio which represents the practical limit of performance achievable. Owing to the high gain of microwave aerials, an erp of 10 kW can be obtained from a transmitter power of only a few watts.

Frequency allocations within the 7 GHz band are based on CCIR Recommendation Number 385, originally prepared for telephony systems of 300 channels.

Frequency planning is based on standard channel allocations of 7 MHz width intended for 300 (bothway) telephone channels. A television system requires four such channel allocations. The return frequencies associated with telephony links are effectively sterilised each time the band is used for television even though private television links are normally required to operate one-way only. Within the more densely populated areas of the UK serious frequency congestion exists within the 7 GHz private user microwave band, and frequently licencing investigations can become difficult and may require prediction of interference levels between systems carrying widely differing types of traffic, i.e. telephony, data, radar or television.

Route Planning

Once it has been established that a re-broadcast link for feeding a station would be impractical and that a microwave link is required, map studies are made for determining the theoretical viability of a microwave feed. An elementary idea of the suitability of proposed locations can usually be formed from examination of Ordnance Survey maps of scale 1:250,000 (about four miles to the inch) on which the contour levels are shown in various colours. High ground and possible line of sight paths can rapidly be spotted, and unsuitable paths can be eliminated quickly before attempting more detailed study. From a short list of sites chosen by this technique, more precise study can be made by plotting the path profiles on earth profile charts, thereby taking account of earth curvature and atmospheric refractive index. In using this type of chart for microwave paths, care must be taken to plot the heights accurately to a suitable scale. The curves on the charts are parabolic and approximate to a real path only if suitable scales are chosen.

Normally, the refractive index of the earth's atmosphere to radio waves decreases linearly with height, and the effect of this is that a microwave beam tends to follow the curvature of the earth. This ray bending can alternatively be considered as an increase in earth radius. Standard atmospheric refraction causes ray bending equivalent to an earth radius of four-thirds that of the true earth. This concept is expressed in terms of an earth radius factor K, so that in normal conditions $K=4/3$. When less bending occurs, this can be represented by a corresponding reduction in the value of K. For a very small percentage of time a value of 2/3 may be obtained, and a path which is free of obstruction at $K=4/3$ may be obstructed at $K=2/3$.

For a path to be usable it must have adequate clearance over obstructions and this is usually expressed in terms of Fresnel zones, see Fig. 2. A Fresnel zone is the locus of a point from which the sum of the distances to the transmitter and receiver aerials is equal to the direct distance plus an integral number of half wavelengths. The first Fresnel zone represents a path length one half wavelength longer than the direct path. The grazing incidence of reflections that occur on a practical path results in a

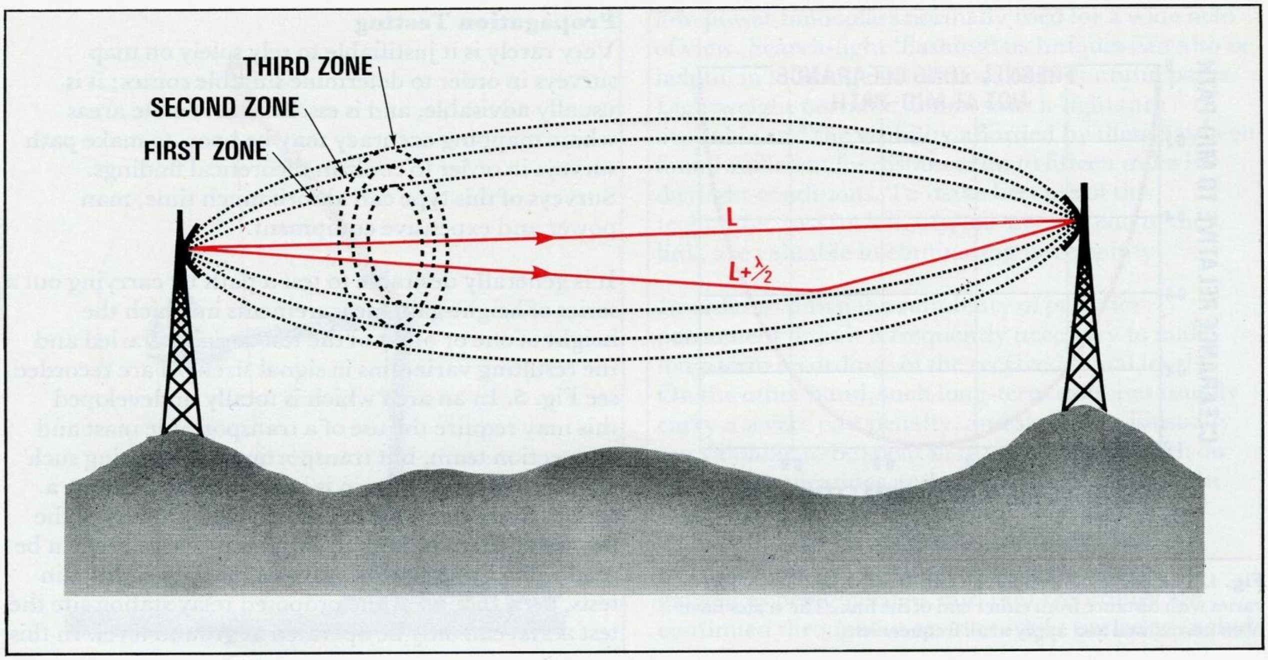


Fig. 2. For good microwave reception the radio path must have adequate clearance over obstructions. The space between the transmitting and receiving aerials can be thought of as being divided into ellipsoidal zones, called Fresnel zones after the French scientist who first described them. The first Fresnel zone is the locus of a point from which the sum of the distances to each link terminal is one half wavelength longer than the direct path. Most of the energy in the wave is contained within this first zone. Reflections at low angles of incidence cause a further half wavelength change of phase so that a signal reflected from an object located in the first Fresnel zone is received in phase with the direct ray and reinforces it. A reflection from an object in the next zone, which will have travelled a distance equal to the direct path plus one wavelength, cancels the direct ray and a 'fade' will occur. The beam width of the aerial encompasses many Fresnel zones, but a signal strength equivalent to that in free space will be received provided that 0.6 of the first Fresnel zone is free of obstruction.

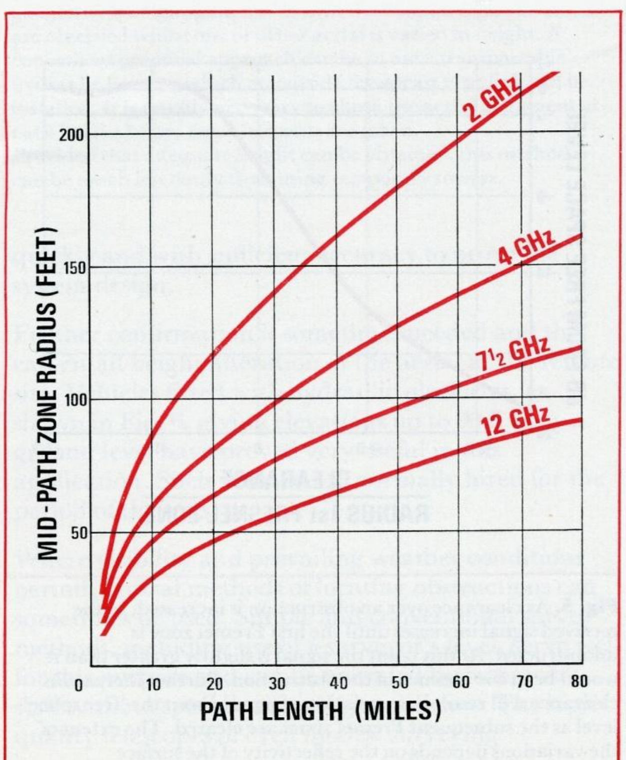


Fig. 3. The radius of the Fresnel zone at the centre of the path depends on the carrier frequency in use. The curves show the first Fresnel zone radii at midpath for four frequencies commonly used for microwave links.

phase change of $\lambda/2$, so that any reflection that takes place from a point on the first Fresnel zone results in a signal which at the receiver aerial adds in phase with the wanted wave. Reflections from the next zone would result in cancellation, and so on. In practical terms, a 40-mile path at 7 GHz has a radius at the mid-point of the first Fresnel zone of about 84 ft, as shown in Fig. 3. Nearer to the terminals the radius

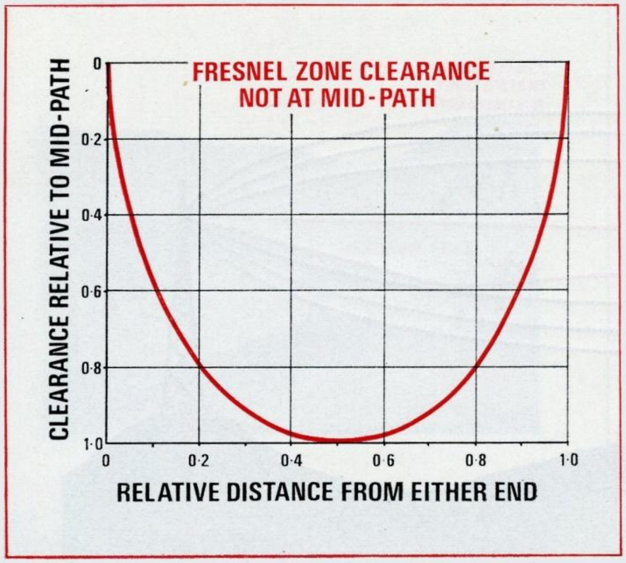


Fig. 4. This curve shows how the radius of the first Fresnel zone varies with distance from either end of the link. The scales have been normalised and apply at all frequencies.

reduces but, because a Fresnel zone is ellipsoidal in shape, at a distance of four miles from either terminal it is still about 50 ft. Fresnel zone clearance at positions other than at the mid-point of the path can be determined from the curve given in Fig. 4.

The criteria used for determining suitability in terms of Fresnel zone clearance are subject to the degree of reliability that is needed. Hence, the requirements of the system specification and the financial considerations can, to some extent, be balanced in accordance with experience. The aim for IBA systems, normally, is to achieve 0.6 Fresnel zone clearance at an earth radius factor of $K=4/3$, coupled with a 0.3 Fresnel zone clearance at $K=2/3$. However, in many instances the latter would require high aerial locations which can be very costly. Depending on the precise circumstances and locations, compromises can be made, and in some cases systems have performed satisfactorily although the path was well obstructed at $K=2/3$. Much depends on weather conditions and precise geographical features.

Any site proposed as the starting point for a microwave path must be checked to ensure that the received signal will be adequate for broadcasting purposes.

Propagation Testing

Very rarely is it justifiable to rely solely on map surveys in order to determine suitable routes; it is usually advisable, and is essential in remote areas where mapping accuracy may be poor, to make path surveys in order to confirm theoretical findings. Surveys of this type can absorb much time, man power and expensive equipment.

It is generally desirable to test a path by carrying out a series of height-gain measurements in which the height of one or other of the test aerials is varied and the resulting variations in signal strength are recorded, see Fig. 5. In an area which is totally undeveloped this may require the use of a transportable mast and an erection team, but transporting and erecting such a mast in difficult terrain is hazardous and can be a serious drain on resources. Fortunately, many of the proposed IBA links are in situations where use can be made of existing towers or masts for the height-gain tests, even though at the proposed relay station site the test aerial can only be operated at ground level. In this way, the location and height of any obstruction or highly reflective area can be determined quite

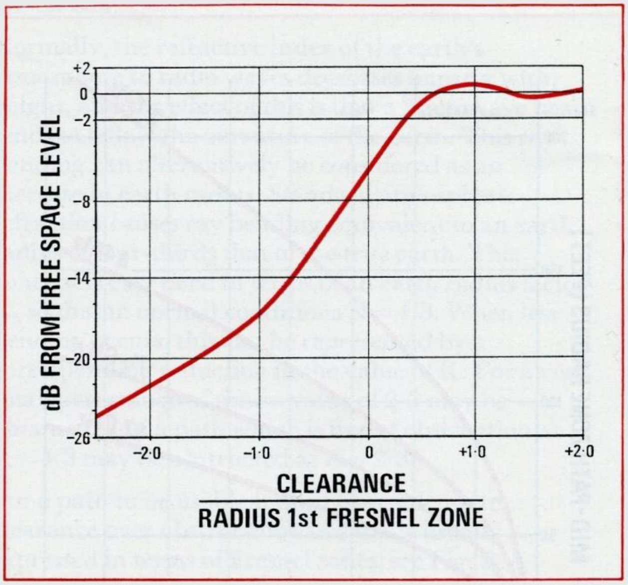


Fig. 5. As clearance over an obstruction is increased, so the received signal increases until the first Fresnel zone is unobstructed. At this point the signal is slightly greater than it would be in the absence of the obstruction. Further increase in clearance will result in a variation of signal about the 'free space' level as the subsequent Fresnel zones are cleared. The extent of the variations depends on the reflectivity of the surface illuminated by the radio beam.

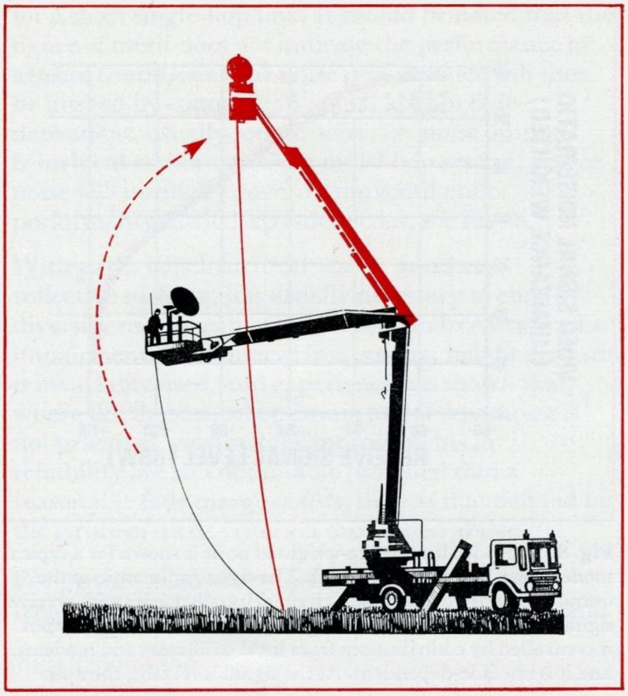


Fig. 6. The suitability of a proposed microwave path can be gauged by a height-gain test in which the signal level variations are observed whilst one or other aerial is varied in height. A convenient practical approach can be to use a transportable hydraulic hoist on which an outside broadcast type link can be installed. It is usually necessary to check the aerial alignment at each height before measurements are taken.
Provided that adequate height can be obtained, this method can be much less costly than using temporary towers.

quickly and with sufficient accuracy to prove the system design.

Further confirmation is sometimes needed and this can entail height alteration of the aerial at the remote site. Vehicles fitted with hydraulic platforms, as shown in Fig. 6, giving elevations up to 90 ft above ground level have proved very useful in this application. Such vehicles are normally hired for the period of the tests.

Where visibility and prevailing weather conditions permit, optical methods of locating obstructions can sometimes be used. Simple and conventional survey methods, including use of a surveyor's level, serve well for this purpose and can be operated by technician staff without special surveying experience. The high quality telescopes of even modest surveying instruments can be a valuable supplement to low-power binoculars normally used for a wide field of view. Search-light 'flashing' techniques can also be helpful in locating obstructions over doubtful paths. Lightweight portable Zenon search-lights are available and the visibility afforded by these has been found sufficient for distances up to fifteen miles in daylight conditions. To make best use of this technique, two such lights, one at each end of the link, are valuable in eliminating uncertainty.

In order to prove the suitability of paths for permanent links it is frequently necessary to make long-term recordings of the received signal levels. On the other hand, such long-term exercises usually carry a severe cost penalty, and staff-time is usually too valuable to be spent in maintaining a watch on the communications and recording equipment. In the UK, experience has shown that it is generally feasible to limit recordings to one or two days provided that the propagation conditions can be gauged as being normal, and that recordings are continued throughout an over-night period to include the effects of evening and early morning atmospheric variations. The use of reliable recording instruments during these tests is most important as valuable effort can be wasted if either the recording chart or pen mechanisms should fail.

System Design

Following propagation tests it is usually possible to establish the aerial heights necessary for each hop. These determine the requirements for support structures. Once the aerial heights are known, the total losses between transmitter and receiver can be estimated, and the requirements of the equipment to achieve the desired noise performance can be defined. This is usually done by a simple 'losses and gains' calculation. Losses in the system include the path loss, feeder losses and losses in filters, circulators and other components used for interconnecting the equipment and aerial systems. The estimated total of these losses is set against aerial gain and equipment capability, and the net result must be a practical system which will offer adequate performance and reliability at a reasonable cost.

In comparing the merits of possible alternative system combinations it can be helpful to use the concept of a 'figure of merit' defining the equipment performance in respect of noise under fade conditions. In this context, the figure of merit signifies the difference in decibels between the transmitter power output and

the noise level present in the first stages of the receiver. The figure of merit M, can be expressed as

$$M = P - F - N$$

where M = rf figure of merit in dB

P = transmitter power in dBW (available at the transmitter output)

F = noise figure of the receiver in dB (measured at the input port)

and N = basic noise in dBW (proportional to absolute temperature and to the rf bandwidth of the receiver).

For example, a system which uses a 1 W transmitter with a receiver having a 40 MHz bandwidth and a 10 dB noise figure will result in a figure of merit of $M = 0 - 10 - (-128) = 118$ dB. This is also illustrated diagramatically in Fig. 7.

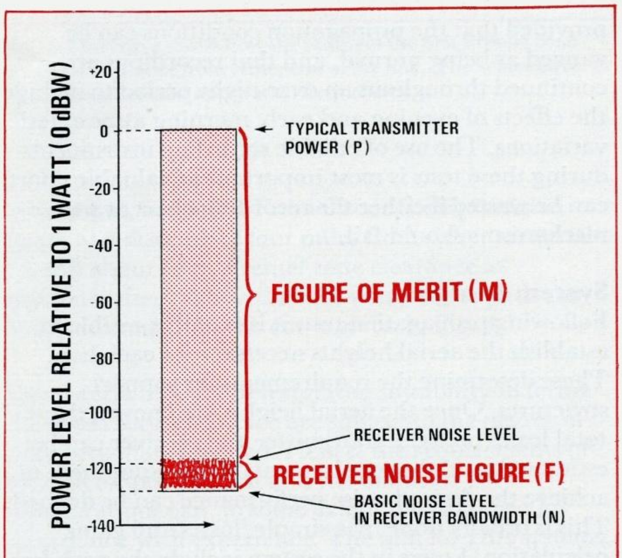


Fig. 7. A convenient way of defining the performance of radio link equipment is to use the figure of merit. This is the difference, expressed in dB, between transmitter power and receiver noise level which controls the noise performance of a link during fade conditions. Basic noise power in watts can be expressed as kTB where

$k = 1.36 \times 10^{-23}$ watts/°K (Boltzmann's constant)

B = bandwidth in Hz

T = absolute temperature in °K

The bandwidth of a typical microwave receiver is 40 MHz giving a basic noise level of −128 dBW. For a receiver having a 10 dB noise figure the resulting noise is −118 dBW, and if the transmitter power is 1 watt (0 dBW) the corresponding figure of merit is 118 dB. Higher transmitter power, or a lower receiver noise figure, will result in a higher figure of merit.

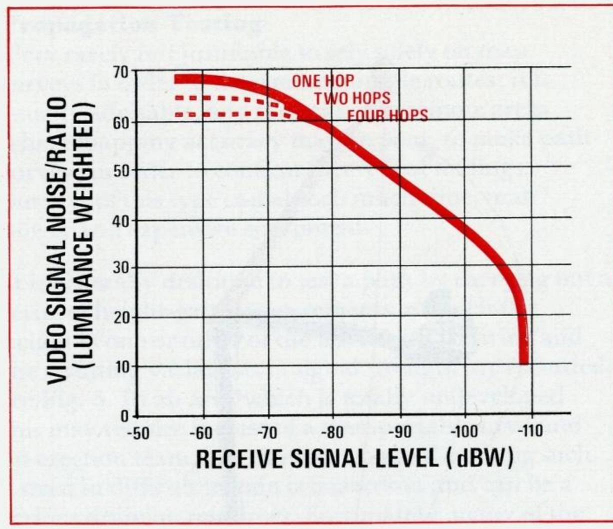


Fig. 8. The video luminance-weighted noise is shown for a typical modern one-hop microwave link. The signal/noise ratio at the output of any fm transmission channel usually varies with received signal level as shown here. At high signal levels the noise output is controlled by contributions from local oscillators and modems, and it is not fade-dependent. As the signal level falls, the noise contributed from the receiver input stages increases and becomes predominant. Noise then increases proportionately as the signal level drops until a threshold is reached when the carrier/noise ratio is about 10 dB. The dotted curves show the effects of additional hops on which the fading is assumed to occur at different times.

When the required figure of merit of a system has been defined, a choice can usually be made from available standard equipment for obtaining optimum combinations. One such combination might comprise a transmitter using travelling wave-tubes to produce a high transmitter power whilst another of lower transmitter power might achieve similar results by featuring a receiver having an improved noise figure resulting from a special design of mixer, or other means.

IBA systems are normally defined with a figure of merit sufficient to ensure that, with an 18 dB fade on the longest hop in the system, the noise impairment on a television picture would be imperceptible. This will usually ensure satisfactory noise performance for 99% of the time, even if Rayleigh* fading occurs. This rule may be relaxed in special circumstances. For example, it would result in an uneconomic design

*Lord Rayleigh (1842–1919), in his studies of wave propagation of sound signals, calculated mathematically the probability of fading that would be caused by multiple interference which is totally random in amplitude and phase.

for a short single-hop link. It should be noted that the figure of merit does not indicate the performance in *unfaded* conditions. The noise performance will then be limited by components which are not fade-dependent, usually source noise, i.e. noise output from local oscillators. On a multi-hop system, source noise will normally govern the overall noise performance until deep fades occur, see Fig. 8.

With paths which are over water, or other reflective surfaces, it is usually necessary to employ diversity reception in order to remain free from noise impairment. To conserve frequencies, height diversity is invariably used, and experience has shown that, where the theoretical optimum aerial separation is not practical, worthwhile improvements in reliability are still obtainable provided that a reasonable fade margin exists, such as that defined by the figure of merit criterion mentioned above.

For private microwave links the CCIR recommendations defining standard signal levels and deviations for international connection are usually adopted. It is worth noting, however, that applying the recommendation for an audio sub-carrier results in the subjective performance of the system being limited by noise on the sound channel during fade conditions. Furthermore, the recommended pre-emphasis characteristic results in a video performance that is limited by noise first appearing in the chrominance channel. In the case of terrestrial links, the design limits are usually not critical, but for satellite systems provision of, for example, an additional fade margin of 2 dB can result in an extremely expensive penalty in terms of pay load and launching costs.

Off-Air Input

A remote site for re-broadcast linking requires a high-quality off-air reception system feeding the microwave transmitter. The arrangement must have high overall reliability and be suitable for unattended operation.

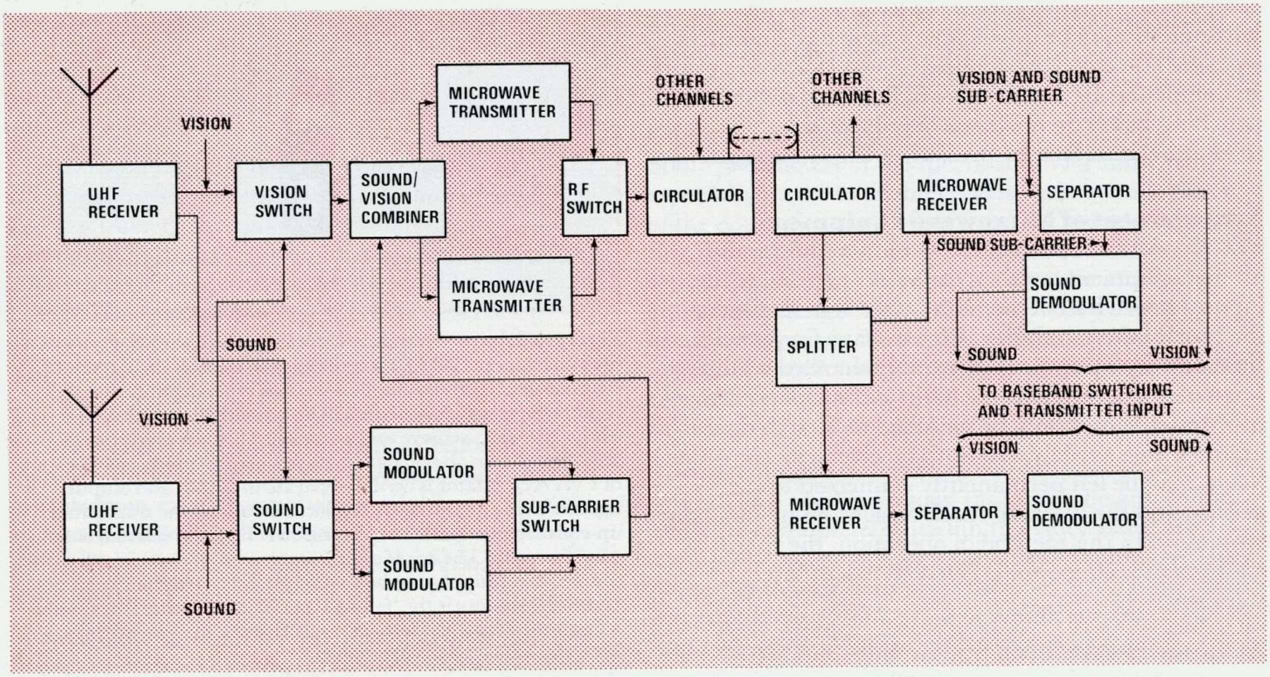


Fig. 9. This diagram shows the arrangement of equipment for a single-hop re-broadcast microwave link. It will be seen that all active equipment is duplicated, and arrangements are made for automatic changeover in the event of a failure in the main channel. Dual receiving aerials feed a pair of uhf synchronous receivers. The vision and sound outputs are separately switched and then split to provide the inputs to both microwave transmitters which operate on the same carrier frequency. The output from the working transmitter is fed to the aerial, and the reserve transmitter feeds into a dummy load until required. Other channels sharing the same aerial system are combined by means of circulators.
At the receive site, circulators separate the channels. The signals are then split to drive both the main and reserve receivers each of which deliver a vision and sound output. One vision and one sound signal is then selected to drive the broadcast transmitter.

The equipment, which is shown in block diagram form in Fig. 9, comprises a pair of receiving aerials feeding two high-quality receivers, and from these the vision and sound outputs are separately selected to provide the working channel. Vision selection is conditional upon monitoring the presence of satisfactory sync pulses on a receiver output; similarly, audio selection depends on the presence of a pilot tone of 22.5 kHz which is broadcast at low level above the frequency band of the sound programme signal.

The receivers used by IBA have been specially developed for the application of re-broadcast reception. They feature synchronous detection for eliminating the effects of quadrature distortion and crystal-derived local-oscillator signals are used for positioning the carrier accurately on the receiver characteristic. These features enable reception of colour television signals with very little impairment of the radiated broadcast quality. A built-in test transmitter enables the performance to be checked independently of the parent transmitter. Other refinements may be introduced where circumstances require. These include automatic waveform correctors for compensating for selective fading, and diversity switching based on the levels of noise and co-channel interference present on the video signal.

Arrangement of Microwave Equipment

The vision and sound signals so obtained from the off-air equipment are then each split to provide the inputs to each half of the microwave system. Owing to the restricted availability of microwave frequencies, the stand-by equipment invariably shares the same frequency allocation as the main channel, and hence transmitters must only be switched to their aerials one at a time as required. Both receivers, on the other hand, may be left permanently connected to the aerials, and the working receiver selected by baseband switching. In this method of operation, the spare equipment is colloquially referred to as a 'hot stand-by'.

At the microwave link input the video signal occupying a baseband of 5.5 MHz is pre-emphasised and combined with a 7.5 MHz sub-carrier containing the audio signal, in accordance with CCIR Recommendation 402. These signals frequency modulate a 70 MHz oscillator to provide a composite i.f. signal which after power amplification is up-converted to the final microwave frequency. Drive to the up-converter is derived from a crystal controlled chain of amplifiers.

For high-power systems broadband amplification may follow the up-converter. This may take the form of an IMPATT diode amplifier, an example of which is shown in Fig. 10, or a travelling-wave tube amplifier, e.g. Fig. 11. The working transmitter is chosen by means of a waveguide switch, usually solid state, and a system of circulators and filters combines its output with those of other channels carrying other programmes, possibly BBC1 or BBC2, to share a common aerial, as shown in Fig. 9.

At a receive station, channels are separated by means of filters and circulators and are normally split to provide equal input signals to the main and stand-by receivers. Occasionally, a switched input system giving unequal receiver signals in the ratio of about 10:1 may be used to provide the highest possible signal level to the working receiver whilst the stand-by is still fed with sufficient signal to enable continuous monitoring of its performance. However, the added switching for this arrangement introduces

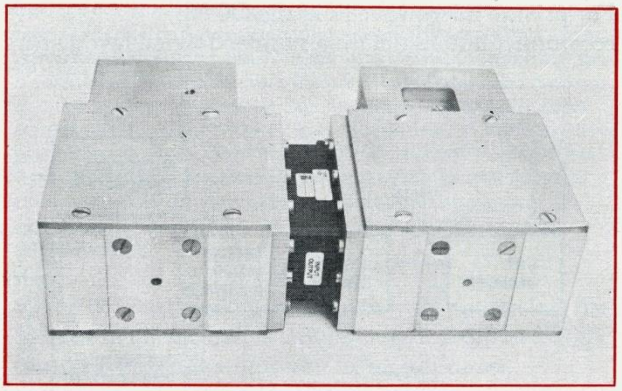


Fig. 10. Microwave transmitters of intermediate output power, may incorporate IMPATT amplifiers to raise the broadband output signal level. In amplifiers of this type, the negative resistance of a suitably biased diode mounted in a waveguide cavity is used to achieve microwave amplification. In the amplifier shown above, two stages are used to produce an output of 1 W. A circulator is used to separate the input and output signals. Using broadband amplification allows the transmitter up-converter to operate at lower-power levels which makes for good linearity. The use of a solid-state amplifier and its relatively simple power supply can be a valuable aid to reliability. An additional feature is the 'fail-soft' performance whereby, should a single diode fail, the amplifier will operate at reduced gain; thus, total channel loss is avoided.
(Photograph by courtesy of G & E Bradley Ltd.)

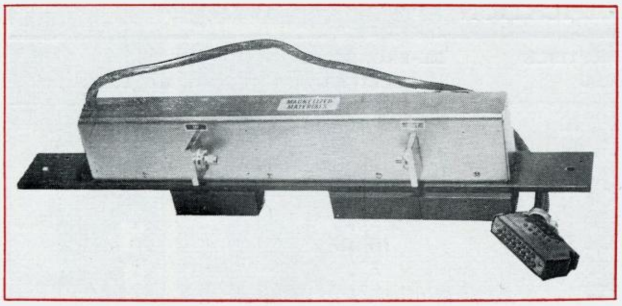


Fig. 11. Travelling Wave Tube (TWT) amplifiers are normally used in microwave transmitters requiring more than about 1 W of rf output. As the only thermionic (i.e. non solid-state) device in a modern transmitter, the TWT with its associated high voltage power supply has hitherto limited overall equipment reliability. Traditionally it has consisted of a magnetic focusing mount, within which the vacuum tube is separately replaceable. However, increased efficiency resulting from continuous development has permitted reductions in the size of the mount, in particular the collector cooling assembly, so that it has become feasible to supply the mount and tube as a single lightweight package. In this way any problem of interchangeability between tubes and mounts is eliminated, thereby achieving optimum tube focusing, rf performance, and operating life.
(Photograph by courtesy of M-O Valve Company Limited)

a complexity which can be undesirable especially on multi-hop links.

The received rf signal is down-converted to an intermediate frequency of 70 MHz, and a band-limiting filter eliminates adjacent-channel interference while maintaining a flat amplitude and group delay characteristic. An i.f. amplifier with agc is followed by an adjustable group delay corrector which is normally set to equalise any group delay error occurring in the preceding hop.

A 70 MHz demodulator produces the video and a 7.5 MHz subcarrier which is further demodulated to yield the audio output. In this way video and audio outputs from each channel are available simultaneously, but there may be further switching before these signals are applied to the broadcast transmitter.

Intermediate stations use identical receivers and transmitters, but they are interconnected at i.f. thus forming non-demodulating repeaters.

System Performance
The performance of the overall system must be controlled such that the subjective effects of distortions at the end of the transmission chain are contained within the limits of acceptability. A table of the distortion limits which represent the level of signal errors just perceptible to a viewer is given below, and the corresponding performance specification for a re-broadcast receiver and a long microwave link are also shown separately for comparison.

It will be noted that the equipment specifications are somewhat severe in comparison with the subjective limits, but this is necessary in order to maintain the quality of the overall transmission from studio to domestic receiver.

The complete transmission chain may include a television camera, studio mixers, video tape recorders, a long chain of network links, a main broadcast transmitter, possibly one or more relay transmitters and ultimately the home receiver. The specification of each item in the broadcasting chain is controlled within practical limits in order that the end result shall be acceptable to viewers equipped with suitable domestic aerials. The specification for individual items may be so stringent that the distortion is difficult to measure. As a result, the test equipment used to set up and maintain the network must be both accurate and sufficiently rugged to withstand field usage.

Equipment Design
Some parameters of the specification for links are especially prone to problems arising in certain parts of the equipment and often these are revealed for the first time when colour television and sub-carrier sound signals are transmitted. Often the aim of the equipment designer is directed towards achieving good performance for telephony, and although this will also be sufficient for many of the requirements for television there remain a few problems whereby television signals present special problems.

The first of these is the requirement to accurately reproduce a waveform such that both the amplitude and phase components within the video band are accurately received. Obviously, this requirement does not apply to telephony transmission, nor is it met by any particular specification of amplitude/frequency response alone. The vision/sound sub-carrier separation filter at the system output usually presents the most severe design task in this respect, and will thus impose a practical limit on the performance obtainable.

Another difficulty arises from the need to carry signals having a bandwidth extending down to dc through an essentially ac transmission path. Unless due

TECHNICAL SPECIFICATION

PARAMETER[1]	JUST PERCEPTIBLE LEVEL	RE-BROADCAST RECEIVER	SHF LINK
2T pulse-and-bar ratio	4% K	0.25%	1% K
2T pulse response	4% K	1% K	1% K
50 Hz square wave response	4% K	1% K	1% K
Chrominance-luminance gain	+26% −37%	±2%	±4%
Chrominance-luminance delay	200μ S	10 nS	10 nS
Line time non-linearity	25%	1%	2%
Differential gain	25%	1%	2%
Differential phase	35°	1°	1°
Video signal noise ratios			
i Unweighted	39 dB	49.5 dB[3]	—
ii Weighted luminance	45 dB	—	60 dB[2]
iii Weighted chrominance	41 dB	—	54 dB[2]
iv LF noise	45 dB	56 dB	48 dB

Notes

[1] The parameters are defined in *IBA Technical Review 2.*

[2] 18 dB fade on longest hop.

[3] 2 mV input level.

allowance for this is made, conflicting requirements for the 50 Hz waveform test and for the step-response or 'bounce' test can lead to problems, especially on tandem baseband connections.

A severe test of overall transmission accuracy is presented by a current CCIR recommendation on channel spacing which demands that microwave channels be spaced by only 20 MHz. This is difficult enough for high-capacity telephony, but an even greater problem for television with a sound sub-carrier. Crosstalk from the vision signal into the sound channel is the most sensitive parameter, and differential gain and phase distortions a close second. Unless the channel separation can be achieved without steep rises in group delay at the edges of the pass band, these requirements can be extremely difficult to meet. The problem is made easier by the recent introduction of test equipment which will explore group delay variations in the transmission band with a search frequency close to the colour and sound sub-carrier signals, but this does not of itself ensure the required equipment linearity in both amplitude and frequency. IF and rf channel separation filter design is the critical factor, and for 'multi-hop' links in particular care must be taken to avoid aggravating the problem by allowing excessive am/pm conversion in, for example, up-converters where it would create delay errors from amplitude variations across the relevant frequency band.

In contrast to these problems, the performance of modems required for high-density telephone traffic is such that they will normally handle television signals without introducing measurable linearity errors. The pre-emphasis characteristic helps in this by reducing the dynamic excursion at low frequencies.

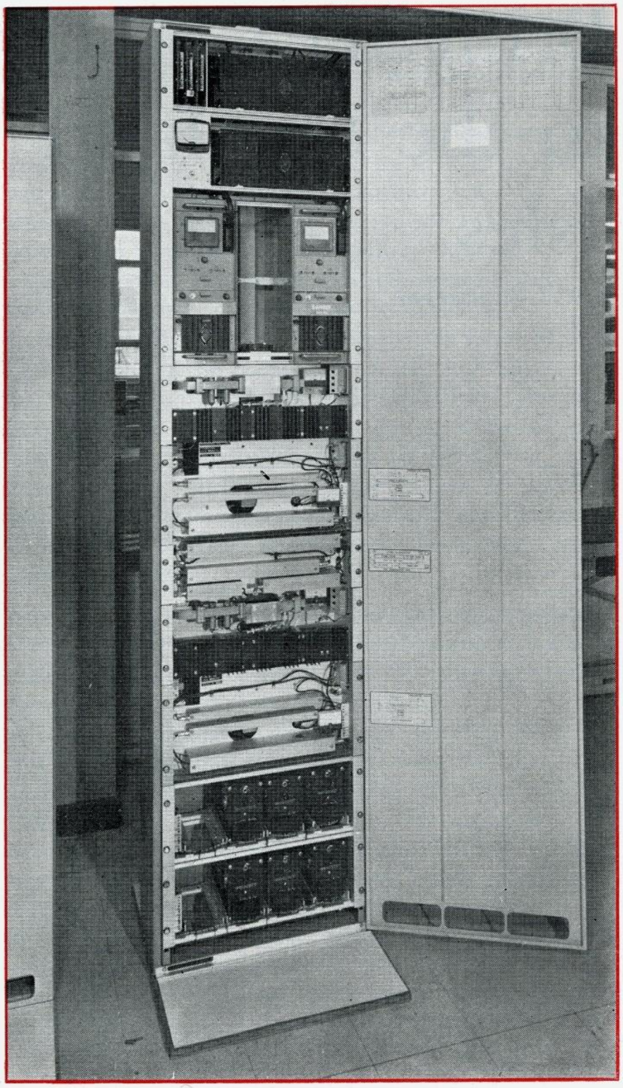
A photograph of a modern 7 GHz microwave transmitter rack is shown in Fig.12.

Conclusion

The foregoing describes briefly the special requirements of microwave links for extending broadcast television coverage, and indicates how the different technologies for microwave transmission and for television broadcasting are brought together in practice.

Microwave links are the most reliable of all the many kinds of technical installation operated by IBA, and represent the most cost-effective method of linking to remote or technically 'difficult' transmitter sites without sacrificing quality.

When television broadcasting in the UK is allowed to expand into the fourth programme service for which engineering provision has already been made, the demand for microwave linked transmitting stations will increase. Future developments will make for even higher reliability, and the inevitable reduction in



the size of equipment will correspondingly reduce the need for building space, increasing the cost-effectiveness of microwave links in broadcasting still further.

Congestion in the 7 GHz band will eventually cause the higher frequency private-user band at 13 GHz to be exploited, and if digital transmission becomes desirable even higher frequency bands, at present unlicenced, may be necessary in order to preserve homogeneity in the use of these bands.

Fig. 12. Shown here is a 7 GHz microwave transmitter rack incorporating duplicate 10 W travelling-wave tube transmitters operating on a single frequency 'hot stand-by' arrangement with a solid-state rf output selector switch. The switching operation is controlled automatically by means of rf level and modulation detectors. A 625-line colour television signal, together with its associated 15 kHz audio signal on a 7.5 MHz sub-carrier, forms the base-band signal. For a service of this type, an rf channel arrangement with carrier frequency separations of between 28 and 49 MHz is normally used. However, demands on the limited spectrum available have made it necessary to restrict the utilised bandwidth as far as possible. The equipment illustrated here achieves the full broadcast link specification over several hops on the basis on a 24.5 MHz channelling plan.
(*Photograph by courtesy of Ferranti Limited*)

GERRY SANDERSON
joined the Authority from the Post Office in October, 1955, shortly after the first ITV station opened at Croydon.
As a Lines Engineer he was partly responsible for the acceptance testing of nearly 90% of the Authority's vision and sound network installed by the Post Office, starting with the programme feeds to the Lichfield Station.
He was instrumental in starting the Authority's first laboratory and workshop, which was destined to blossom into the present Experimental and Development Department. He also carried out the first propagation tests for the Authority and so was surely the precursor of the present Service Area Planning Section.
As a member of the Network Planning Section he is now Project Engineer in charge of installing the link feeding 625-line colour signals to the new uhf transmitting station to be installed at Bressay on the Shetland Islands.

Bringing Colour to the Shetland Isles

by G L Sanderson

Synopsis

The extension of the television services to some of the remoter parts of the United Kingdom is beset, among other things, with the problems of getting suitable input signals to the appropriate relay transmitters. Because such areas may not be within reach of signals radiated from other transmitters, and because the established Post Office links are not available beyond the nearest principal towns or cities, special *ad hoc* provisions have to be made, usually by the broadcasting authorities themselves.

A case in point is the link to the new Shetland uhf transmitting station on the island of Bressay, near Lerwick, which is due to be brought into service towards the end of 1976. Signals from the Keelylang Hill transmitter on Orkney (IBA channel 43) will be taken off-air at Fair Isle, which fortuitously is most conveniently situated approximately mid-way between the two island groups of Orkney and Shetland, and relayed to Bressay by means of a 7 GHz microwave link. Both the uhf and shf link terminals at Fair Isle and Bressay respectively make use of diversity reception techniques to minimise the effects of fading which can result due to the long oversea paths involved.

The equipment to be installed on Fair Isle will be housed in an ex-wartime radar station building, suitably converted, and since there is no commercial electricity supply available on the island, three 31 KVA 3-phase diesel generators will be provided in a separate specially-constructed building just over half a mile away. A major problem, however, is the supply and storage of an adequate quantity of fuel to enable services to be maintained throughout the long winter season when landing of the delivery vessel is likely not to be possible on account of severe weather conditions.

Introduction

From any of a number of the IBA's various publications, e.g. the ITV Handbook, the reader will probably know already that ITV programmes for the northern areas of Scotland originate either directly or indirectly from the studios of Grampian Television in Aberdeen. It is from here that the

programme signals are fed via a Post Office link first to the IBA transmitter at Durris for local transmission of the 625-line colour service on channel 25, and then northwards to the uhf relay station at Rosemarkie operating on channel 49. These signals from Rosemarkie are also picked up by high quality receivers, developed within the Authority for this purpose, at the IBA transmitting station at Rumster Forest near Lybster, Caithness, where they are re-broadcast on channel 24. From Rumster Forest they are received on the Orkney Islands at Keelylang Hill and are re-radiated on channel 43. The next link in the chain, from Keelylang Hill to the new uhf transmitter on the Isle of Bressay, just off Lerwick in the Shetland Islands, has proved to be the most difficult one to forge and were it not for the small island of Fair Isle, one of the Zetland group of islands standing alone in the Atlantic Ocean between Orkney and Shetland, it would have been even more difficult, see Fig. 1.

When investigations were first made into the method of feeding Bressay with television programmes it was realised that a direct path of over 100 miles between the two terminals was too long for either a re-broadcast link (RBL) or a super high frequency (shf) microwave link alone. It was then that the decision was taken to use a mixture of the two, with Fair Isle as the intermediate point. Transmitted signals from the Keelylang Hill transmitter would be received at Fair Isle, 66 miles away, by the same type of high quality receivers referred to above using diversity feed trough aerials combined with masthead amplifiers and, by means of a 7 GHz shf link, these would be extended to Bressay where a diversity system would again be used to overcome the possibility of fading on the oversea path during periods when propagation is bad. As, like all transmitting stations in the uhf network, Bressay is shared with the BBC it is logical that the method of feeding it should be similarly shared. In fact, it was the BBC who carried out the first propagation tests which proved the Fair Isle/Bressay path. However, the building and installation of the Fair Isle facilities, including the RBL and shf aerials, have been provided by the Authority in co-operation with the Post Office, though the BBC are responsible for installing their own electronic equipment.

Fair Isle is a small island approximately three miles long by $1\frac{1}{2}$ miles wide. It has a closely-knit community varying in number between 70 and 80 persons and consisting mainly of crofters but including members

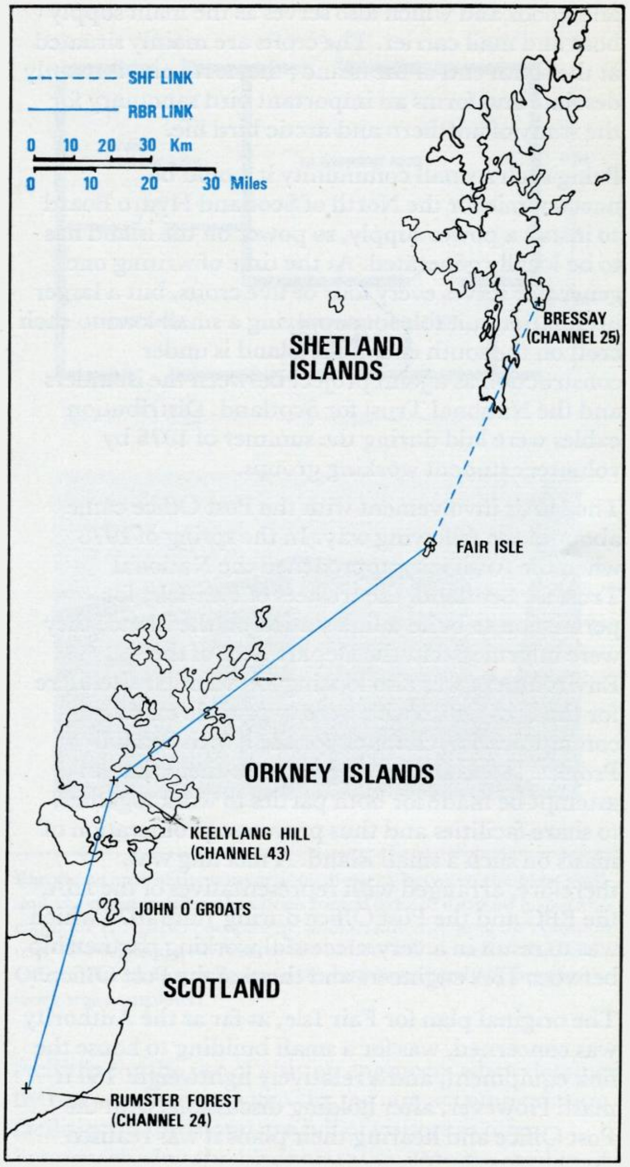


Fig. 1. The 100-mile link from Keelylang Hill to the new Shetland station at Bressay has to be installed in two sections. The radiated uhf signal from the transmitter at Keelylang Hill, serving the Orkney Islands, is received at Fair Isle and re-transmitted on a 7 GHz microwave link to Bressay.

of the Scottish Lighthouse Board staff, the Bird Observatory staff and the island nurse, all with their respective families. Access to the island is achieved from the Shetlands either by a chartered twin-engine 'Islander' aircraft or by the *Good Shepherd III*, a Brixham trawler converted for carrying passengers

and goods and which also serves as the main supply boat and mail carrier. The crofts are mainly situated at the south end of the island; the north end is mainly desolate and forms an important bird sanctuary for the study of northern and arctic bird life.

Being such a small community it would be uneconomic for the North of Scotland Hydro Board to install a power supply, so power on the island has to be locally generated. At the time of writing one generator serves every four or five crofts, but a larger installation suitable for supplying a small load to each croft on the south end of the island is under construction as a joint project between the islanders and the National Trust for Scotland. Distribution cables were laid during the summer of 1975 by volunteer student working groups.

The IBA's involvement with the Post Office came about in the following way. In the spring of 1973 when the Authority approached the National Trust for Scotland, the trustees of Fair Isle, for permission to build a link station on the island, they were informed that the Department of the Environment was also looking for a similar site there for the Post Office who were to provide extra communication channels for the North Sea Oil Project. It was further suggested to them that an attempt be made for both parties to work together, to share facilities and thus prevent a proliferation of masts on such a small island. A meeting was, therefore, arranged with representatives of the IBA, the BBC and the Post Office during June 1973 which was to result in a very successful working partnership between IBA engineers and those of the Post Office.

The original plan for Fair Isle, as far as the Authority was concerned, was for a small building to house the link equipment, and a relatively lightweight 150 ft mast. However, after holding discussions with the Post Office and hearing their plans it was realised that a larger building would be required, and a much larger tower.

Propagation Planning

Having chosen a route, the next part of the exercise was to investigate, with the aid of Ordnance Survey maps and profile charts, whether or not it was possible to obtain a workable path between Keelylang Hill and Fair Isle, and between Fair Isle and Bressay.

Keelylang Hill has a mean aerial height of approximately 880 ft above ordnance datum with a clear path out to sea towards Fair Isle in which direction the aerial pattern has been designed to give its maximum erp of 100 kW. The signal then passes over a 66-mile path to Fair Isle, $61\frac{1}{2}$ miles of which is over the sea.

As already mentioned, it is because of this very long sea path that it was decided to install a diversity system at Fair Isle with aerials at 25 ft and 150 ft and, to improve the signal-to-noise ratio, a mast-head amplifier is to be fitted to each. To further enhance the signals over this very long sea path automatic video correctors will be fitted which will make use of test line signals inserted on lines 19, 20, 332 and 333 of the video signal to correct most of the distortions likely to be present on the incoming signal particularly overall signal level, bar tilt, 2T pulse amplitude, 2T pulse shape, and luminance/chrominance gain and delay inequalities.

At the time of the initial planning the Keelylang Hill transmitter had not entered service. It was, therefore, impossible to carry out any long term reception tests as is usually done when planning the more difficult paths. Decisions had, therefore, to be made purely on theoretical considerations. It is a well known fact that in the field of propagation theoretical decisions cannot always be relied upon to hold in practice. It was for this reason that when assessing the wind-loading for the tower on Fair Isle allowance was made for the erection of a further two 10 ft diameter shf aerials on the south face to enable the possible provision of a diversity system via Sanday or North Ronaldsay at some time in the future should the RBL prove to be totally unsatisfactory.

The Fair Isle/Bressay path, which is $44\frac{1}{2}$ miles long, is virtually a line of sight path as Ward of Cairn, on which the Bressay transmitting station stands, is visible from the Fair Isle site on a clear day. But here again, 31 miles of the path is over sea and hence a diversity system, this time at shf, is being installed using two 8 ft diameter aerials at 15 ft and 80 ft above ground level, i.e. 736 ft and 801 ft above ordnance datum respectively. A further help is the existence of Ward Hill, just north of Sumburgh Airport, Shetland, which tends to shield the receiving aerials from the indirect reflected signals off the surface of the water. These would otherwise be likely to arrive at the aerials out of phase with respect to the direct, wanted signal and thus cause fading.

The Link Building

The first visit to Fair Isle was made in July 1973

by a party consisting of representatives of the Post Office, the Department of the Environment and the Authority, and an inspection was made of a number of ex-wartime buildings which had formed part of a naval radar station. One building, a disused generator station, stood out as being most suitable with regard to both layout and position for a clear path to Bressay. This building, standing at a height of 525 ft aod, consisted of the generator housing, a room 25 ft × 18 ft 6 in × 13 ft high, with a 10 ft 6 in blast wall enclosing two sides, Fig. 2.

It was decided that the best way to modify the building was to roof over the area between the blast wall and the side of the main building. This would form a smaller apparatus room which would conveniently house the IBA/BBC equipment, and the remainder of the area would be fitted out as an amenity area with four bunks, toilet and cooking

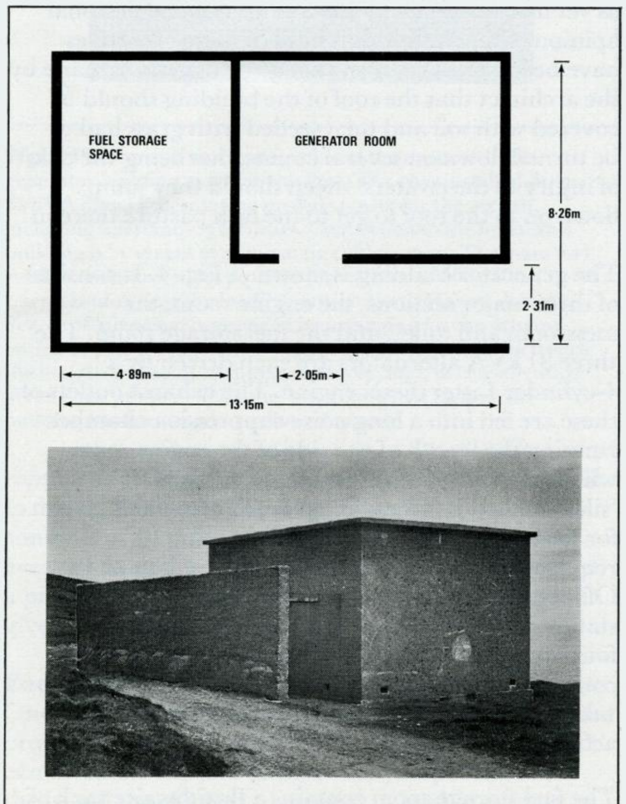


Fig. 2. The link equipment on Fair Isle is housed in a converted ex-wartime radar building. The illustration shows an outline plan and a photograph of the building as it was prior to reconstruction.

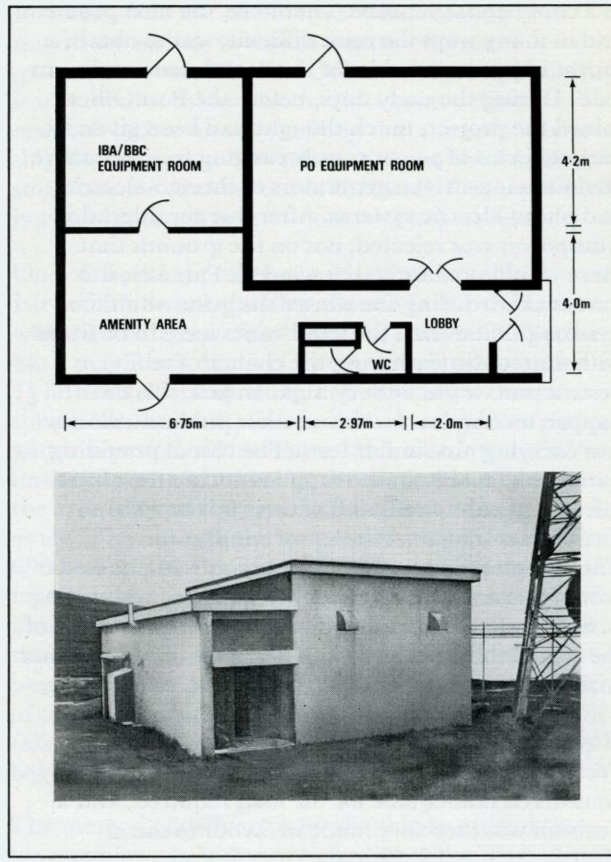


Fig. 3. As part of the conversion, the area between the blast wall and the main buliding has been roofed over to form an apparatus room for IBA/BBC equipment, and an amenity area for common use. The original generator room has been allocated to the Post Office. The photograph shows the building shortly before the work was completed.

facilities for the use of visiting engineers when detained by bad weather, or when the meagre accommodation facilities on the island are full of visitors as often happens during the bird migration seasons, see Fig. 3. The building operations have now been completed and what was originally an eyesore has been turned into a respectable looking building by use of a suitable cement rendering over the existing roughcast walls. All building work for the project was carried out under the control of the Authority.

The Generator Station

In the introduction it was pointed out that because of the small population of Fair Isle it was not economical to provide power facilities on the island

as a commercial venture. Therefore, the next problem, and in many ways the most difficult, was to obtain a source of power suitable for the calculated maximum load. During the early days, before the Post Office joined the project, much thought had been given to various forms of power supply ranging from the more obvious wind-driven generators to thermo-electric and photo-electric systems. After due consideration windpower was rejected, not on the grounds that there would not be enough wind on Fair Isle, but that at times during the winter the gusts would be so strong that even if the wind vanes were to be fitted with automatic feathering the chance of self destruction would be very high. In fact, this did happen on Shetland when another public authority was carrying out similar tests. The cost of providing batteries to maintain the supplies during the albeit infrequent calm spells and of their upkeep was a further factor against the use of windpower. Thermo-electric supplies were discounted due to the cost of fuel and the difficulty of supplying and storing it. Solar cells were turned down mainly on account of the cost of the units and supporting batteries, together with the lack of strong sunlight in this area.

However, with the inclusion of the BBC and the Post Office in the scheme such supplies were considered inadequate for the load required, and a decision was therefore made in favour of diesel electric generators. Calculations of maximum power requirements, including heating and ventilation in both the technical areas and the amenity area, were carried out by all three parties and resulted in a maximum total requirement of just under 25 kW (31 kVA).

At one of the early planning meetings it was decided that the IBA should be responsible for all the building work on the island, together with the tower, and that the Post Office should be responsible for the provision and distribution of power supplies, including the import and delivery of fuel. Division of the cost of providing the power, after having split the capital costs, would then be on a metered demand principle.

Based on the calculations mentioned above, the Post Office agreed to install three 31 kVA 3-phase generators thus permitting one to be used as duty generator, one as stand-by and one as a maintenance spare so there should always be one reserve generator readily available even during a major overhaul. Together with these generators would be the associated control gear for automatic or manual change-over as required.

Meanwhile the Authority's architect went ahead with the design of a suitable building to house the generators and the main fuel storage tanks capable of holding 14,000 gallons of diesel fuel, just over twelve months supply at normal running. The specification for the design of the generator building stipulated that the noise level, with one generator running, should not exceed 55 dB when measured at the edge of the site, nominally 10 ft from the building. In the event it was decided that the generator building should be situated in a disused open-ended quarry about a third of the distance between North Haven, where the oil would arrive, and the link building some half-mile further on at the top of the hill. Not only would this reduce any noise reaching the Bird Observatory hostel at South Haven but it would also prevent the building becoming an eyesore in an as yet unspoiled part of the island. It is the personal opinion of the author that both of these objectives have been achieved even though a suggestion made by the architect that the roof of the building should be covered with soil and then seeded with grass had to be turned down on several counts, one being the risk of injury to the crofters' sheep should they jump down on to the roof to get to the lush pasture thereon!

The generator building is shown in Fig. 4. It consists of three major sections, the engine room, the messroom and toilet, and the fuel storage room. The three 31 kVA alternators are each driven by a 4-cylinder Lister diesel engine. The exhaust outlets of these are fed into a long noise-suppression chamber running the length of one side of the engine room which thus provides a very high degree of 'silencing'. It is not expected to fully load this system for several years to come as the planning requirements have taken account of long term Post Office plans. Distribution of the power to the link station is accomplished by means of two parallel four-core cables forming a ring main to protect continuity of supply. Naturally, steps have been taken to balance the loads on each phase as accurately as possible.

The fuel storage room contains a Braithwaite tank of approximately 16 ft × 13 ft × 10 ft which has been divided into three sections to prevent total loss of oil should a leak occur. All seams have been both welded and secured with nuts and bolts; also the floor of the

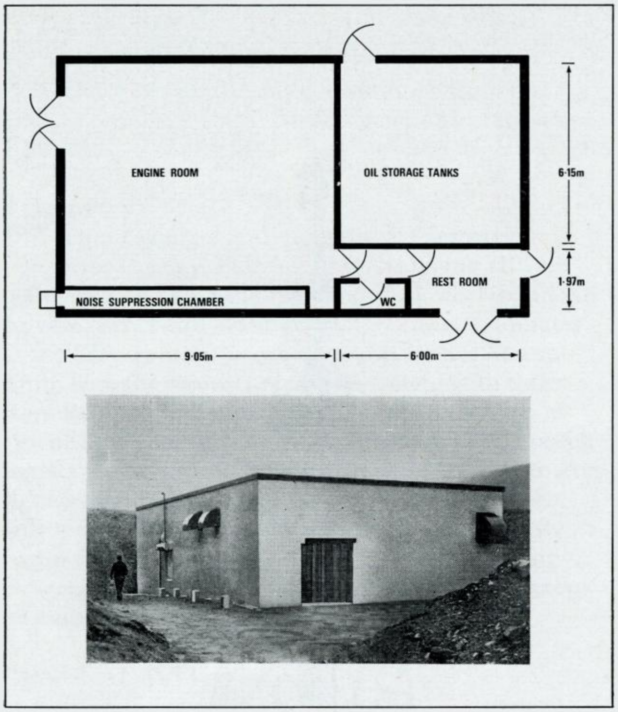


Fig. 4. Photograph and outline plan of the purpose-built generator building in which the Post Office has installed three 31 kVA diesel generators to provide power for the project, including full stand-by facilities. Connection to the apparatus building is by means of a ring main cable system. The main fuel storage tanks are fed by pipeline direct from a 7000 gallon reservoir tank near the loading jetty at North Haven. A high degree of 'silencing' is provided by arranging for the exhaust outlets to pass through a noise-suppression chamber which runs the length of one side of the engine room, and, in consideration of the noise problem and other environmental factors, the building has been sited in a disused quarry.

room is sunk below ground level and is proofed inside to form a bund or sump large enough to contain the contents of all three sections without spillage in the event of an accident. The tanks are filled by means of a pipeline from North Haven details of which are given below.

Fuel Supply

One of the biggest problems connected with this project has been to establish the means by which fuel can be efficiently and economically imported on to the island in sufficient quantities to enable services to continue over fairly long periods when, due to weather or other reasons, deliveries could not be made. The normal method used by the islanders is to ship the fuel in 40-gallon drums on the *Good Shepherd III*, but this would not be practical when dealing with quantities such as twelve to fourteen thousand gallons per year. The Post Office, whose responsibility it was to solve this problem, did a great deal of research before finally deciding that the only way to ship the fuel was in 600-gallon tanks on the *Islander*, a small coaster working out of Kirkwall, Orkney, which is available for charter for journeys to Fair Isle.

One of the main problems with shipping to Fair Isle is that the only landing place is in North Haven where a small jetty 200 ft long has been built, but this has a maximum depth of water at high tide of only $1\frac{1}{2}$ fathoms. Consequently, any ship larger than a trawler has to get in, tie up, unload and get out again within a period of four hours, otherwise it is stuck until the next high tide. All the tankers available in the area have too large a draft for them even to enter safely – hence the proposal to use ten 600-gallon tanks loaded on to a coaster. To make matters even more difficult there is a large rock almost in the middle of the entrance which implies that even the small coaster has to wait for ideal weather conditions before attempting an enter. This, of course, precludes any guarantee that deliveries will take place at all between the end of October and the beginning of May.

The method of delivery is for the ship to unload the ten complete tanks one at a time on to the jetty using its own derricks. They will then be emptied and reloaded on to the ship. It was realised during the planning that by using a mobile pump of reasonable size it would not be possible to pump 6,000 gallons of fuel directly to the generator station 170 ft up the hill and a quarter of a mile away in the time available. To overcome this a 7,000 gallon reservoir tank has been housed in a small building on the shore at North Haven into which the oil is pumped from the tanks on the jetty at a high rate via a fairly level underground pipeline. When the delivery vessel has departed with the empty tanks, the mobile pump is moved from the delivery point on the jetty to the reservoir tank building where it is connected into a different part of the system to pump the fuel, at a slower rate, up the pipeline to the main storage tanks in the generator station. Further, following a request on behalf of the islanders by the National Trust for Scotland, provision has also been made for a short extension to be added to the pipeline from the jetty to North Haven which will allow the islanders to use the jetty terminal for filling a tank of their own, which

they will install later, enabling them to buy their diesel oil in bulk at cheaper rates. The mobile pump will also be available to assist them in this enterprise.

The Tower

As was mentioned earlier, when the Post Office joined the Fair Isle consortium, the proposed specification for the tower had to be drastically altered. From a relatively light 150 ft stayed mast for carrying the receiving trough aerials and the Yagi aerials for the radiotelephone, and having the shf aerial mounted on a short separate structure or on the roof of the building, it became a 150 ft tower capable of supporting up to fifteen 12 ft and two 10 ft parabolic reflectors, two trough aerials and three 12-element Yagis, see Fig. 5. Only five 12 ft reflectors are being mounted in the first instance; one for the IBA/BBC and four for the Post Office who plan to erect the other ten as required over a period of the next forty years. The possible provision of the two 10 ft reflectors by the IBA/BBC will depend on whether the operation of the RBL proves satisfactory as explained earlier.

The tower complies with the normal basic type of construction used elsewhere by the Authority and the Corporation, but at the request of the Post Office a central feeder-supporting spine has been added and provision has been made for walkways and platforms to be constructed behind each dish position, although, for economical reasons, at the time of writing these have only been fitted to the aerials so far installed.

It is well known that Fair Isle experiences some of the highest surface wind speeds in the United Kingdom. Because of this the mast has had to be designed with a fully loaded windspeed factor of 158 miles per hour for a three second gust, and hence it is a very sturdy looking structure weighing over 32 tons without the aerials or feeders.

Bressay

The Fair Isle end of the link installation, having produced the more interesting problems concerning the building, transport, power, accommodation, etc., has been fully described in the foregoing, but a brief description should, however, be made of the Bressay installation.

At Bressay there already exists a BBC vhf station which is fed by shf link with signals picked up at the southern end of Shetland direct from the Orkney vhf transmitter at Fitful Head.

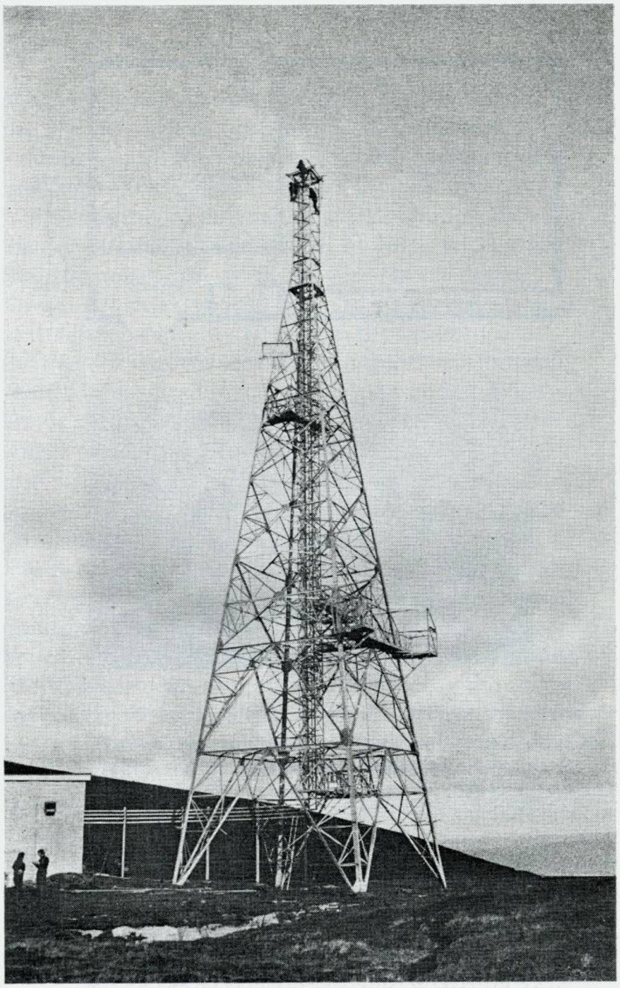


Fig. 5. The aerial tower on Fair Isle has been designed to accept a maximum loading of fifteen 12 ft and two 10 ft parabolic aerials with a fully loaded windspeed factor of 158 mph during a three second gust. The photograph shows the tower just after completion, before erection of the first batch of aerials.

To provide for the new IBA/BBC uhf transmitters the BBC is constructing a new building and erecting a new 257 ft tower to support two 8 ft diameter shf aerials respectively at 15 ft and 80 ft levels. Each of these aerials is cross-polarised, as is the one on Fair Isle, in such a way that vertical polarisation will be used for BBC1 and BBC2 and horizontal polarisation for ITV and, hopefully, Programme 4. Flexible waveguide type 14 is used at both ends of the link except inside the building at Bressay where rigid

waveguide is preferred on account of the large bending radius required for the flexible type.

Power supplies for Bressay are obtained from the Scottish Hydro-electric Board's generator station at Lerwick.

Telemetry

IBA remote control and supervisory telemetry signals for Bressay, Fair Isle and Keelylang Hill are being carried by a radiotelephone link working in the private users band around 465 MHz and terminates at the IBA transmitting station at Rumster Forest. From here the signals are carried, along with those from Rumster Forest itself, to the control station at Durris by means of a Post Office private wire. Speech signals are carried on this circuit as well, the telemetry signals being separated by filters, but signalling is only available between the control station and any one of the stations *en route*, or vice versa. Signalling between intermediate stations is not available except by audio monitoring.

GENERAL DATA

	FAIR ISLE	BRESSAY
Map Reference	HZ 213 732	HU 503 387
Site Heights (aod)	525 ft	743 ft
Mast Heights (agl)	150 ft	257 ft
RBR Aerial Heights (agl)	25 ft and 150 ft	—
SHF Aerial Heights (agl)	20 ft	15 ft and 80 ft
Reflector Diameters (Focal Plane)	12 ft	2 × 8 ft

Path Lengths: Keelylang Hill to Fair Isle – 66 miles (uhf)
Fair Isle to Bressay – 44.5 miles (shf)

SHF Polarisation: Cross-polarised (BBC vertical IBA horizontal)

Fibre glass radomes fitted to all dishes to reduce wind loading.

IBA (shf) transmitter output power: 0.5 watt (nominal)

Receiver noise figure 7.5 dB.

Bressay transmitter frequencies IBA 7477 MHz BBC1 7452.5 MHz BBC2 7501.2 MHz

Conclusion

An attempt has been made in the foregoing to briefly survey the problems which can arise in an otherwise straightforward exercise of supplying a programme feed to a uhf television transmitter in the IBA/BBC chain of stations bringing the 625-line colour service to remote parts of the British Isles. Although the system is not due to become operational until the latter part of 1976, the Authority's engineering staff are confident of its ultimate success.

Obtaining Sites for Transmitting Stations

by R M Bicknell and J S P Burton

ROLAND BICKNELL, was educated at the Mid-Essex Technical College and School of Art, where he specialised in architecture and building. As Head of the Independent Broadcasting Authority's Site Selection Section, he has been finding sites for the Authority during the past fourteen years. Previously he was employed by a firm of consulting engineers whose clients included the Marconi Company Ltd. and the Independent Television Authority, and in that situation he was closely involved in the civil engineering aspects of the first twelve ITA vhf transmitters. He is married with one daughter and two grandchildren, and lives in Hampshire.

STAN BURTON was born and educated in Cornwall. He started his career with the South Western Electricity Board in 1950 as a Draughtsman/Surveyor and, subsequently, as a Wayleave Officer.
He transferred, in 1961, to the Central Electricity Generating Board where he was associated with the Planning and Wayleaving of 275 kV and 400 kV overhead transmission systems, and the selection of power station sites. In 1972 he joined the Independent Broadcasting Authority as a Site Selection Engineer. He is married with three sons and lives in Winchester.

Synopsis

The only component part of a transmitting station which cannot be specified, designed or manufactured is the land on which it is situated. Yet, the location and nature of the site affect not only the design and function of the station itself but the whole intricate pattern of any broadcasting network, be it uhf television or mf sound radio, of which it might form part.

This article describes the investigations necessary to site selection, the methods used in overcoming the various problems which arise in the course of negotiations with landowners, and the processes that eventually lead to the acquisition of sites.

Particular reference is made to Town and Country Planning legislation, public opposition to the erection of aerial structures, and to various legal aspects of site acquisition.

Introduction

Much of the Authority's early work lay in establishing a network of high-power vhf main transmitting stations for the 405-line black-and-white television service. The selection and acquisition of sites for these stations, despite the large areas required and the much higher aerial structures necessary, was, to a certain extent, a simpler matter than acquiring sites for the relatively modest low-power uhf relays which form part of the more recent 625-line colour service.

The main reasons for this are three-fold; first, in those early days the public were clamouring for an alternative television service and, in general, local authorities took pride in having important television transmitting stations within their boundaries. Similarly, certain landowners were pleased to accommodate such stations on their properties. Also, because the aerial support structures were so tall, no Town and Country Planning Authority ever considered trying to enforce their concealment.

By the early to mid 1960s, the planning for a duplicated ITV service in uhf, which lacked the promise of another new programme, did not elicit the same enthusiasm from the public. Also, by that time there was a growing awareness of the need to conserve the countryside, and, because the proposals for the uhf service required a separate and very much more extensive network of transmitting stations, each far more critically sited than those forming the vhf service, objections were received from increasingly large numbers of the local conservationists.

In the case of uhf relay stations, the three basic problems, correct location, obtaining planning permission and negotiating terms for acquisition, are more difficult. Thus, as much effort and even more time is usually required for investigating and acquiring a site for a relatively small uhf relay transmitter as was necessary for a main vhf station.

Since 1964, when the IBA and BBC joined forces in establishing a network of co-sited uhf television transmitters capable of providing up to four services (ITV, BBC1, BBC2 and a fourth programme as yet unallocated), the responsibilities for purchasing and maintaining the sites have been equally divided between the two organisations. At 50% of the sites, which will eventually number well in excess of 400, the IBA is the landlord and the BBC is the tenant, and at the remaining sites the roles are reversed. Each organisation uses similar methods of site investigation and acquisition. Certain mutually agreed procedures have been adopted for this work and are from time to time amended in the light of experience and changing circumstances.

The selection and acquisition of sites for local radio transmitting stations generally follows lines similar to those for television transmitting stations, but there are certain differences as detailed later in this article.

The work of acquiring uhf transmitter sites can be classified under three headings:

1 Planning

2 Investigation

3 Site acquisition

In practice, these activities overlap considerably and a constant interflow of information is necessary until the site is finally acquired and construction commenced.

Planning

The initial planning, up to the stage where a technically preferred site can be pinpointed on a map, is done by service planning engineers. The work of site finding commences with the production of a Site Brief which specifies the preferred location, with acceptable tolerances, and states the predicted aerial height above ground level (agl), the area to be served and the estimated population coverage.

Assuming it were possible to design the ideal uhf television relay site, the basic specification would probably contain clauses similar to the following. The site should:

i be virtually in line of sight, at the proposed aerial height, with the desired service area.

ii be in line of sight with the parent main or relay station from which the signal feed is to be taken, and have a sufficiently wide path between obstructions to avoid ghosting.

iii be so located as to be free from co-channel interference and other radio interference.

iv be currently in the ownership of a party willing to sell or lease at an acceptable price.

v be acceptable to the County and District Town and Country Planning Committees (which take account of the views of local amenity societies).

vi be in such a position that the aerial structure will not be a hazard to aircraft.

The above six requirements are essential. In addition, the ideal site should preferably

- vii have a crossfall of not more than about 1 in 50.
- viii be free from subsidence due to geological faults, mining or quarrying operations.
- ix have sub-soil bearing capacity sufficient for supporting the aerial structure without need of sophisticated foundations.
- x have existing vehicular access, or be positioned such that access can be provided at reasonable cost.
- xi be reasonably clear of trees and other large vegetation.
- xii be surrounded by sufficient open land to facilitate the erection of a mast or tower.
- xiii be within reasonable distance of an adequate and reliable mains electricity supply.
- xiv be clear of existing and proposed overhead HT cables.
- xv contain no underground cables, waterpipes, etc.
- xvi be free from legal encumbrances such as restrictive covenants, short term leases, etc.

Items i, ii and iii are not only the responsibility of service planning engineers but also of site selection engineers who must bear these points in mind during their investigations, especially when considering and recommending alternative locations should the preferred site prove unavailable, or unsuitable for any reason.

Figure 1 illustrates such an ideal site. In practice it is rarely found, and the final choice is usually a matter of compromise.

Investigation

The first steps in investigation involve thorough examination at the recommended site and any nearby alternatives which might be considered suitable. Naturally, the landowner or his representative is contacted in advance – it would be most indiscreet to venture upon private property without obtaining the owner's consent – and sometimes it is possible, even at this early stage, to obtain an indication as to whether or not he would be prepared to negotiate. However, it frequently happens that an owner is an absentee landlord acting through an agent, and several weeks might elapse before any definite answer is forthcoming. If the property is administered by a trust or syndicate, these initial enquiries can occupy many months.

Concurrently, ideally simultaneously, with the initial approach to the owner, the local Town and Country Planning Officer is advised of the proposals and his informal views are sought. Increasingly, planning officers are reluctant to forecast the likely reaction of their committee members and an informed opinion is often the result of consideration by the Town and Country Planning Committees themselves after they have consulted local amenity and conservation organisations. Sometimes no reaction at all can be obtained without the submission of an outline planning application.

Approval is sought from the Ministries of Defence and Civil Aviation. With structures of less than 200 ft in height, air navigation authorities seldom offer objection, but sometimes they insist on the provision of hazard warning lights. Local mineral valuers and, in appropriate cases, the National Coal Board are consulted with regard to sub-soil suitability; and, where necessary, consultant geologists are called in to report.

The Central Electricity Generating Board and local Electricity Boards are consulted regarding any plans they might have for the future; although existing overhead power cables are readily visible, there is always the possibility that new ones may be erected in the vicinity of the site. The local Board also is asked to give an estimate of the cost of bringing an electricity supply to the proposed site. The local authority is consulted concerning future residential development and likely population shift. For example, there might be schemes in preparation whereby the proposed service area is likely to become depopulated in the relatively near future. Alternatively, plans for extensive residential development which could significantly affect the planned service area might be in consideration.

Means of site access are investigated at this stage and, in cases where no satisfactory road or track exists, estimates for providing suitable access are prepared.

Reports on these initial investigations are forwarded to service planning engineers either recommending that the site appears favourable and that further technical appraisals such as its suitability for a re-broadcast link (RBL) are merited, or giving reasons as to why the site is unlikely to prove

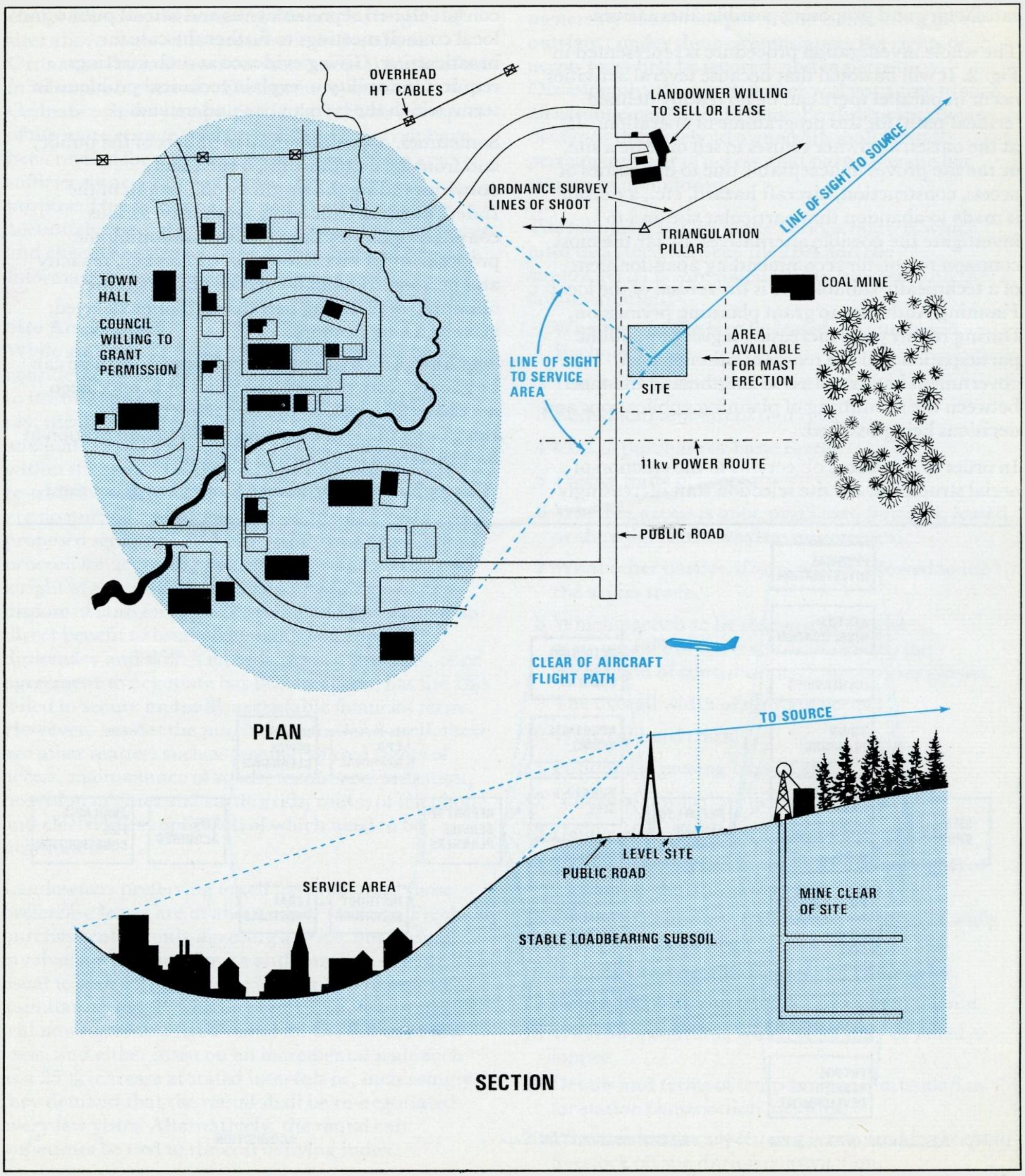


Fig. 1. An ideal site for a uhf television relay station. Such a site has to comply with the sixteen basic requirements listed in the text, and is not often found in practice.

satisfactory and proposing possible alternatives.

The whole investigation procedure is represented in Fig. 2. It will be noted that because several activities occur in parallel there can be no readily defined 'critical path' for this programme of operations. If, at the outset, an owner refuses to sell or lease a site, or the site proves unacceptable due to difficulties of access, construction, aircraft hazard, etc., a decsion is made to abandon that particular site and to investigate the possible alternatives. By far the most common reason for recommending abandonment of a technically suitable site is the refusal of the local Planning Authority to grant planning permission. During recent years increasing legislation, public participation and the reorganisation of local government have resulted in lengthening the time between the submitting of planning applications and decisions being reached.

In order to overcome objections to the erection of aerial structures, the site selection staff increasingly consult elected representatives and attend public and local council meetings to further the case for broadcasting. Giving evidence at such meetings requires the ability to explain technical problems in terms which the layman can understand.

Sometimes, opposition from members of the public, and from local authorities, is such that, notwithstanding the statutory obligations of the Independent Broadcasting Authority, serious consideration must be given to abandoning the proposal altogether. However, diplomacy, tenacity and personality usually succeed, although the obtaining of planning permission is often delayed, even by a year or more.

The Authority's success in matters such as these can be gauged from the fact that it has only once been necessary to appeal to the Department of the Environment. This concerned the ILR mf Station at Saffron Green, just outside London.

Although British Ordnance Survey maps are most

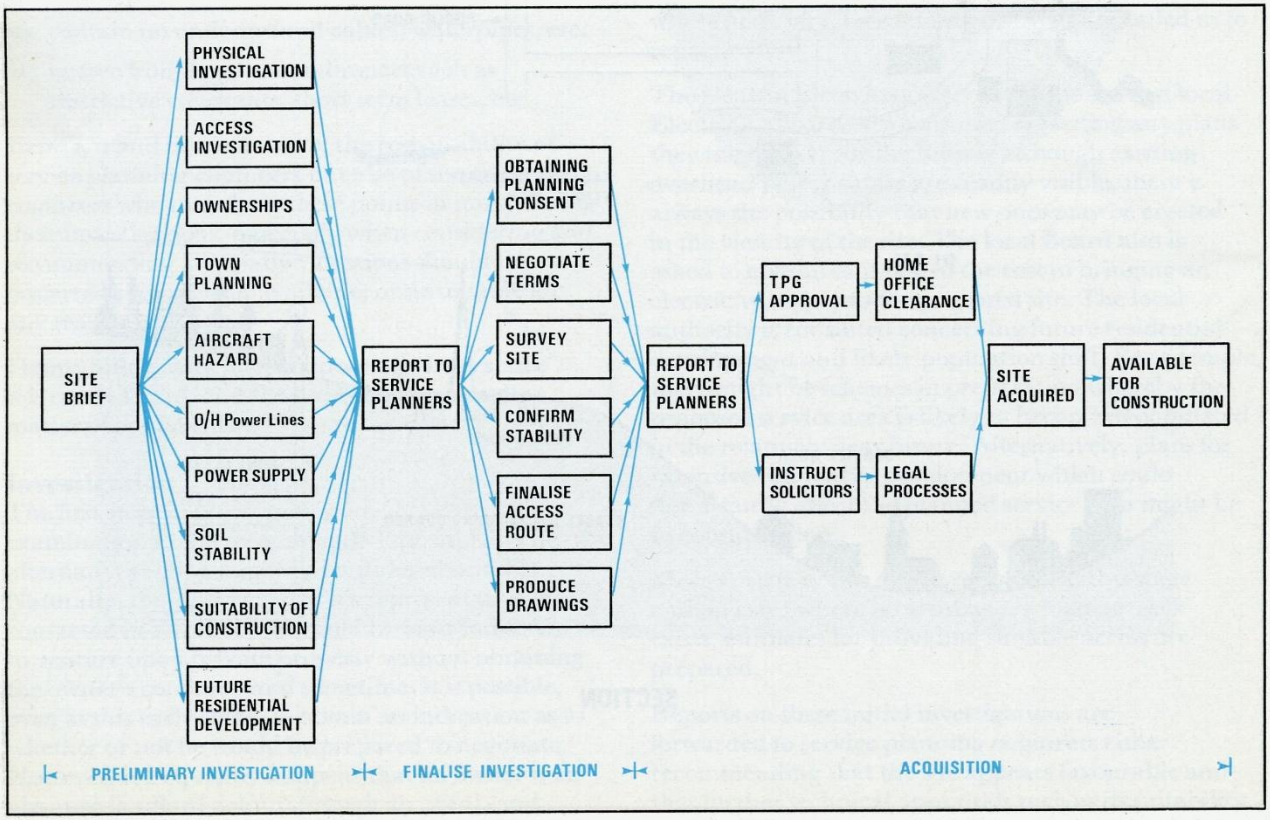


Fig. 2. The essential procedure for investigating the suitability and availability of a proposed site for a transmitting station is shown here diagramatically.

comprehensive, determining the precise heights of sites above sea level (or, more correctly, above Ordnance Datum) involves instrumental work, often in inhospitable terrain. Furthermore, certain Ordnance Survey maps, particularly those in respect of the more remote parts of Scotland, may not have been revised for several years and are not always sufficiently accurate for transmitter siting purpose. Hence, not only is height above sea level accurately surveyed, but the site is carefully measured and checks are also made of the accuracy of relevant information represented on the maps.

Site Acquisition

While an application for planning consent is being considered by the local Authority, the site is tested as to its suitability for a re-broadcast link. That is to say, measurements are made to ensure that an adequate signal can be received from a transmitter within the same IBA region, and that when this is re-transmitted, using the appropriate channel, there are no unexpected propagation difficulties within the proposed service area. At the same time negotiations proceed for acquiring the site and, where necessary, a right of access. Persuading an unwilling owner to dispose of land for a purpose which might seem of no direct benefit to himself demands considerable diplomacy and skill. Yet, only in very few cases, once agreement to negotiate has been reached, has the IBA failed to secure mutually acceptable financial terms. However, besides the purchase of the land itself, there are other matters such as fencing, shared rights of access, maintenance of roads, tenant compensation, provision of gates and cattle grids, routes of telephone and electricity supplies, all of which need to be negotiated.

Landowners preferring to sell freeholds, and those preferring leases are of about equal number. Freehold purchase entails only agreeing a price, but leasing involves agreement of price and duration of lease. It is usual to seek a 21 year lease with option to renew for a similar period. By reason of inflation, few owners will now agree to a fixed rental for the full term of a lease, and either insist on an incremental scale such as a 25% increase at stated intervals or, increasingly, they demand that the rental shall be re-negotiated every few years. Alternatively, the rental can sometimes be tied to the cost of living index.

In some cases, agreement is reached to purchase the freehold of the site, but the route of access is in the ownership of another party who is unwilling to sell outright; under these circumstances the rights of access must first be secured, and in perpetuity. Occasionally, the access owner will not agree to such an arrangement and, because English property law demands that freehold ownership shall include permanent right of access, that particular site has then to be abandoned.

The following is a list of the various matters which must be agreed between the IBA and the landowner(s) before solicitors can proceed with the documentation:—

1 Whether the site is to be leased, or purchased freehold.
2 If leased, the duration of the lease.
3 Period and amount of rent reviews.
4 Cost of purchase or basic rental.
5 Precise route of access.
6 Whether access is to be purchased outright, leased, or the subject of a wayleave agreement.
7 What other parties, if any, will be allowed to use the access track.
8 Which party is to be responsible for the maintenance of the track or, if shared, the proportion of contributions from various parties.
9 The overall width of rights of access.
10 Width of hard track.
11 Positions of passing bays, if any.
12 Nature of finished surface of the track.
13 Details of drainage, positions of culverts, etc.
14 Details of any existing public or private rights of way across the site or access.
15 Details of boundary and any other fences or walls required or requested.
16 Positions and details of gates and cattle grids.
17 Route of power and telephone cables to the site.
18 Where appropriate, which trees may be felled or lopped.
19 Details and terms of temporary accommodation for station construction facilities.
20 Whether temporary fencing is required for keeping livestock off site during construction.
21 Whether unoccupied land is to be grazed and, if so, the terms of a grazing agreement.

22 Whether the IBA will be allowed to sub-let to other users and, on leased sites, whether the landlord will require an additional rental for sub-tenants.

23 Who holds mineral rights? Can they be purchased, and on what terms?

Not infrequently the access is in several different ownerships, and most of the above items have then to be agreed individually with each owner.

When terms have been agreed, planning permission received and the RBL tests have proved that the site is technically suitable, the project is referred to the Television Planning Group, a joint committee comprising representatives of the Home Office. the IBA and the BBC. If this committee approves the project, Home Office agreement to the technical characteristics of the proposed transmitter, e.g. height of aerials, channel frequencies and transmitter power must then be obtained. At about the same time draft legal documents are submitted for approval by both parties. Not infrequently solicitors representing landowners attempt to include clauses in the documents which are at variance with the broadcasting authorities' interests. Sometimes these last minute complications lead to much protracted argument before acceptable legal documents are finally produced, engrossed, signed and sealed.

Sites for ILR Stations

So far, this article has dealt mainly with the selection and acquisition of sites for uhf television transmitters. The investigation and acquisition of sites for sound radio transmitting stations, so far as the IBA is concerned, follows the same general pattern, especially with regard to the vhf ILR stations. However, sites for mf transmitters present special problems in that several aerial structures are sometimes specified. Such a site requires many acres of level ground for accommodating the mast stay blocks and the earth mat. Possibly the greatest problem in siting a comparatively low powered and critically orientated mf ILR station is the need to find a location close enough to the service area yet sufficiently remote from residential development and any installation which could be adversely affected by mf transmissions. These criteria usually demand a location within the Green Belt area which surrounds most large towns and conurbations.

Green Belt areas are jealously guarded and preserved, not only by Town and Country Planning Authorities but by local residents. Hence, not only does the Authority need to overcome the many objections from planners and conservationists, as in the case of some uhf stations, but also many more from individuals and local groups. Most people, however much as they may desire good radio and television services, are unwilling that they should be to the detriment of other local amenities. However, technical requirements seldom lend themselves to compromise, and site selection staff usually succeed in overcoming these objections; but inevitably numerous meetings and discussions must take place and these can introduce much delay. Planning Committees of local authorities usually meet only once a month and conservation societies even less frequently.

The strength of amenity objections, in Green Belt and other similarly protected areas, can best be illustrated by the fact that, for each ILR mf station, an average of 25 sites had to be investigated before planning consent was finally obtained. In the case of the London Station at Saffron Green, more than 200 sites were considered and, even then, the IBA had to appeal to the Secretary of State for the Environment before permission was finally granted.

Because there is no joint IBA/BBC involvement at ILR sites, the investigating and reporting procedures are somewhat different from those relating to uhf television sites. Nevertheless, the procedures previously defined apply in general and, of course, the actual processes of site acquisition are similar for all types of transmitting station.

Generally speaking, ILR vhf sites present few problems because the transmitters can usually be located on existing sites occupied by IBA or BBC television transmitters, BBC radio transmitters or Post Office radio installations. One exception is that of the Portsmouth ILR vhf station at Fort Widley, where the IBA has co-sited with the Home Office and made use of the Fort itself for housing the equipment. Despite the fact that the skyline at Portsdown Hill is a proliferation of aerial structures, radar scanners and electricity towers, the town planning authorities refused the IBA permission to erect an additional structure. Only by agreeing with the Home Office to erect a new tower as a replacement for their existing one of obsolete design, did the IBA obtain planning consent for a station to serve this area.

At the time of writing, the Authority's transmitting stations occupy a total of some 510 acres of land, and the private access roads serving them represent a further 181 acres. If these access roads were to be laid end to end, they would stretch from London to Birmingham, i.e. about 110 miles.

The time taken to investigate and acquire a transmitter site can vary from three months to even five years, depending mainly on what difficulties are experienced with regard to town and country planning.

Safeguarding Amenities

The term amenity in this context relates to those features of landscape which members of the public, individually and collectively, wish to experience and enjoy. It is the aim of amenity planners to preserve or create these conditions.

Clearly the requirements of broadcasting stations often conflict with this concept of amenity. For technical reasons, aerial support structures, be they towers or masts, are themselves tall, and are invariably constructed on high, prominent ground which compounds their visual impact. The problem of reconciling the provision of any popular social amenity, such as radio and television, with the natural amenity of the countryside is quite intractable, and unlikely ever to be fully resolved. However, it is a responsibility of site selection engineers, architects and planners to ensure that, wherever such a construction is needed, it is carried out in a way that is least offensive, not only to the present generation, but to succeeding generations whose attitudes and artistic taste may be different from our own. Therefore, the conflict must be, and is being, faced with imagination and determination in the light of experience gained from other developments which have relentlessly encroached into the countryside, ever since the Industrial Revolution. Site selection engineers are constantly striving to achieve an acceptable balance between the public demand for efficient broadcasting services and the arguments of those deeply concerned with the creation and conservation of amenity and the preservation of the countryside.

Everything designed by architects and civil engineers represents development in terms of the Town and Country Planning Acts, the principal current legislation being the Town and Country Planning Act 1971 covering England and Wales, and the Town and Country Planning Act (Scotland) 1972 for Scotland. Any outdoor development, including demolition, is an intrusion into an established landscape whether it be natural or man-made. Therefore, designers can never be completely preservationist, because they cease to preserve as soon as they accept a design challenge to improve, or change, any existing situation. Conversely, the true preservationist tends to decline an interest in anything new, preferring existing things, probably hallowed by time and familiarity. Such a person might have good emotive cause to prevent others from facing modern technological challenges and from making their own contributions to what succeeding generations might in turn wish to preserve. The planning officer is in a different position, and must be more open minded than either designers or preservationists. Although subject to economic constraints and political pressures, the planning officer bears special responsibility for amenity which is not a single quality but a combination of many values. To the planning officer, amenity extends from natural beauty to architectural and engineering design, all of which can contribute to the pleasant and familiar surroundings which time has evolved, but it also embraces the provision of utilities, public services and modern means of communication involving tall structures.

The planning officer has to balance all the components that contribute to the creation of a pleasant environment and those things, such as broadcasting installations, which are generally regarded as being injurious to amenity. There are other considerations such as rarity, historical and scientific interests which must also be taken into account. These qualities reinforce the argument of preservationists that each generation has a responsibility to posterity, to pass on unspoiled as much as possible of our landscape. We are now approaching the situation where the greater part of our land not already developed has a rarity value, and where it can be claimed that individual sites proposed for new transmitting stations are each in some way unique. This point is often put forward by planning officers and preservationists alike. The Authority recognises this claim without giving the impression that radio and television are always more valuable than the preservation of landscape amenities. At the same time, most planners and environmentalists recognise that radio and television are important to the modern way of life. Faced, then,

with the premise that nearly every site has unique values which can be appreciated but cannot be accurately measured, the IBA has a responsibility to consider each case on its merits, and to consult the planning officer and amenity organisations before making formal application for planning approval on the strength of technical criteria alone, in the hope that public pressure for improved services might influence planning decisions.

A good example of comprehensive consultation between planners, preservationists, and conservationists is the Fair Isle shf link project. As is fully described elsewhere in this edition of *IBA Technical Review*, this required a 150 ft. lattice steelwork tower to be constructed on a prominent part of the island. Fair Isle is certainly unique, and is designated an Area of Outstanding Natural Beauty and of Special Scientific Interest, with a renowned bird observatory. Lengthy negotiations and consultations were conducted with the appropriate Planning Officer, the National Trust for Scotland, the Nature Conservancy and the Countryside Commission for Scotland in order to reach agreement on the site and its layout and design before formal committee approval was granted.

Site selection engineers must maintain a flexible approach to the choice of sites within the technical limits imposed. Occasionally some degree of technical performance might have to be sacrificed, or coverage reduced, if a critical area of landscape can thereby be preserved. Reference was made earlier to the need for siting transmitting stations in high locations, but it must be ensured that these be no higher than absolutely necessary. A movement away from a preferred technical site might reduce impact and help blend stations more sympathetically with their surroundings, possibly by using a belt of trees as a backcloth. In some situations, a stayed mast can be utilised in preference to a self-supporting tower, or vice versa.

A vital compensating factor is the positive contribution that can be made by good layout and design, using these terms in all their engineering, architectural and landscape senses. Where the opposition encountered in respect of a planning proposal is due to a strong in-built resistance to intrusion and change, then good layout and design by themselves will not reduce objection. But man-made structures, however impressive, even when they add perspective to a less interesting landscape, can still offend the eye if the principles of good layout and design have not been applied. It is perhaps unfortunate that, for economic and practical reasons, both materials and designs tend to be governed by standardisation. Consequently, no transmitting station can be completely individually designed in relation to its particular environment. However, as in other fields of design, standards are very important, and in most situations the Authority undoubtedly has applied the right formulae.

At the majority of IBA transmitting stations, the aerials are supported by lattice steelwork structures, the designs of which are simple and effective throughout their height range. Within the UK these are usually much preferred for nearly all types of landscape. Neutral coloured, and with a matt finish of weathered galvanising, they offer the least conspicuous outline when viewed against hills and woodland, or on the skyline. It would, however, be very wrong to pretend that their upper parts and aerials can be completely concealed in any landscape, however carefully they may be sited. What the site selection engineer attempts to do in conjunction with the planners, is to mitigate to the greatest possible extent the effects of intrusion without jeopardising the purpose for which the station is being built. In this way, it is hoped to influence and obtain the support of the preservationist and conservationist, however reluctantly this support might be forthcoming.

Published by the Independent Broadcasting Authority ***Printed in England by The Hawkesby Printing Co. Ltd.***

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